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SUCCESSION AND RANGE OF MESOZOIC AND TERTIARY FLORAS[1]

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X

It is of course a truism to say that the transition from the Paleozoic to the Mesozoic is not, as was once supposed, an abrupt or catastrophic change, but was brought about so gradually that in many parts of the world it is often difficult, if not indeed impossible, to draw any sharp lines. Not only are the rocks lithologically similar, but a certain percentage of life-forms persisted from the one to the other, yet when each system is considered in its entirety there are apparent abundant lithologic and strongly marked biologic differences. It is my purpose to speak briefly of the floras, first of the Mesozoic and later of the Tertiary.

Triassic.—Rocks of Triassic age are known in many parts of the world and indicate two types of deposition, a fresh-water, marsh, or lagoon phase, and a marine phase. The former is only, or largely, that which has afforded a flora. The known plants of the Trias are relatively few in number. In North America we have less than 150 species, and the entire Triassic flora probably does not exceed 300 or 400 forms. Owing to considerations, physical and otherwise, concerning which there is not complete agreement, the lower portions

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of the Trias afford but scanty remains, and it is not until we come to the upper portion, or Rhaetic, that it can really be dignified as a flora. Our North American Triassic flora is believed to belong largely to this portion. Triassic plants have been doubtfully reported from Prince Edward Island, but they are so obviously of Permian types that they may be disregarded. The principal areas are in North Carolina, Virginia, and Pennsylvania, with relatively few in Maryland, New Jersey, Connecticut, and Massachusetts. In the west we have a doubtful plant or two from Wyoming, a considerable number from northern New Mexico, the extensive fossil forests of Arizona, and a very few species from Plumas County, California. Going southward we have small collections from Sonora, from about the City of Mexico, in Honduras, Chile, and western Argentina. In other parts of the world Triassic floras have been found in England, east coast of Greenland, Spitzbergen, North Germany, southern Sweden, Italy, southwestern Spain, Persia, India, China, Tonkin, Japan, New South Wales, New Zealand, and South Africa.

What, now, are the characters of the Triassic flora? The dominant types of the Paleozoic have largely disappeared. The Lepidodendrae, Sigillariae, Calamites, Cordaites, Sphenophyllae, and Cycadofilices, so far as ascertained, have all gone, as well as a number of important genera of ferns—*Cheilanthites*, *Mariopteris*, *Megalopteris*, etc. The most notable survival from the Paleozoic is the so-called *Glossopteris* flora, which has been found with a few associated forms in Rhaetic rocks at Tonkin, the Stormberg series of South Africa, New South Wales, etc.

The Triassic flora consists essentially of equisetums, ferns, cycads, and conifers of many genera. A few forms such as *Ginkgo*, *Cladophlebis*, *Thinnfeldia*, etc., had a small beginning in the Paleozoic and expanded in the Mesozoic into large groups. But most of the flora is of distinctly Mesozoic and northern origin.

It has often been said that the plants of the Triassic are depauperate and pinched in aspect, indicating unfavorable climatic conditions. The paleobotanical facts do not altogether bear this out. In North Carolina, Virginia, and Arizona, there are trunks of trees preserved, some of which are 8 feet in diameter and at least 120 feet long, while hundreds are from 2 to 4 feet in diameter. Many of the

ferns are of large size, indicating luxuriant growth, while Equisetum stems 4 to 5 inches in diameter are only approached by a single living South American species. The cycads are not more depauperate than those of subsequent horizons, nor do they compare unfavorably with the living representatives.

The complete, or nearly complete absence of rings in the tree trunks indicate that there were no, or but slight, seasonal changes due to alternations of hot and cold, or wet and dry periods. The accumulations of coal—in the Virginia area aggregating 30 to 40 feet in thickness—indicate long-continued swamp or marsh conditions, while the presence of ferns, some of them tree-ferns, indicate on the whole a moist, warm, probably at least sub-tropical climate.

Jurassic.—Coming, now, to the Jurassic, we find in the lower portion indications of a continuation of conditions which obtained in the upper portions of the Trias. The distinctive Paleozoic elements had finally disappeared, and the Mesozoic life-forms were in full swing, expanding in the middle and upper parts of the period into the abundant and widespread flora as we know it. In fact the relative uniformity and wide extension of the Middle and Upper Jurassic flora is one of the most interesting and impressive exhibits that we have. (See map showing approximate distribution of Triassic and Jurassic flora.)

There is no paleobotanical evidence indicating the presence of the Jurassic in Eastern North America. In the western interior Jurassic plant-bearing beds occur in the Black Hills, South Dakota, and the Freezeout Hills, Carbon County, Wyoming. We then pass to the Pacific coast, where we have a fine flora near Oroville, California; also northward in Trinity and Tehama counties, California, and Douglas and Curry counties, Oregon.

The following is an outline of the world distribution of the flora:

Alaska	Copper River District
	Cook Inlet
	Herendeen Bay
	Cape Lisburne
England	Yorkshire
France	Mamers—northwestern portion
Germany	Franco-Swabian area
	Northwestern area

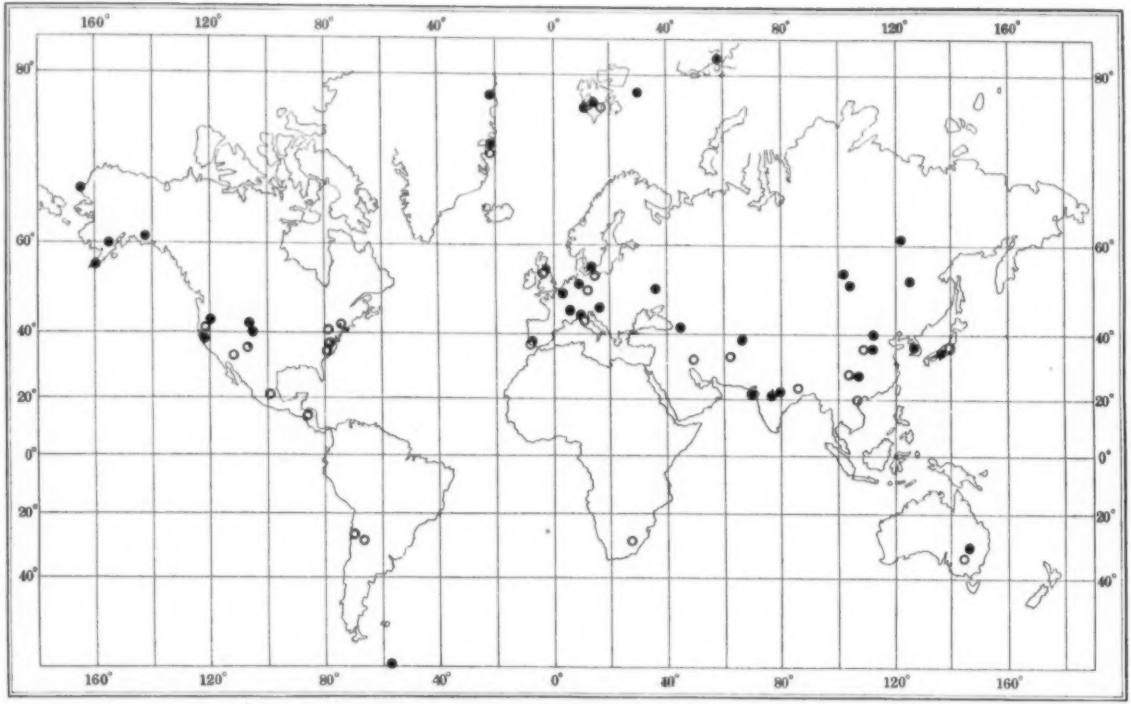

FIG. 1.—Map showing approximate distribution of Triassic and Jurassic floras.

Rings = Triassic
Dots = Jurassic

Austria-Hungary	Steierdorf in Banat
	Crojie in Galicia
	Cracow
Italy	
Switzerland	
Portugal	
Sweden	Bornholm
	Bjuf
Spitzbergen	Cape Boheman, 78° −22′ N.
	Advent Bay, Cape Staratschin
	Green Harbor
King Karls Land	78–79° N.
Franz Josef Land	82° N.
Greenland	Cape Stewart
	80° N.
Siberia	Ust-Balei 51° N.
	Irkutsk
	Upper Armour River
	Lena River District
Corea	
Japan	
Caucasia	
Turkestan	
India	Cutch
	Jabalpur
China	Tyrkyp-Tag
	Border Hami Desert
Australia	
New Zealand	
Louis Philippe Land	63° S.

The flora of the Jurassic, while in the main a continuation of that of the late Trias, and consisting of equisetums, ferns, cycads, ginkgos, and conifers, shows the incoming of a number of more modern types in these groups. The cycads were of course abundant and diversified, whence it has been called the age of cycads. The flora is remarkably uniform over wide portions of the world. Thus not far from 50 per cent. of the North American flora—exclusive of the cycad trunks—is the same as that found in Japan, Manchuria, Siberia, Spitzbergen, Scandinavia, or England, and what is even more remarkable, the plants found in Louis Philippe Land, 63° S., are practically the same as those from Yorkshire, England.

Some idea of the climatic conditions which prevailed at this time may be gained from the present distribution of certain obvious descendants of the Jurassic flora. Thus *Matonidium* and *Laccopteris* are represented by *Matonia* of which there are two species living in the Malay region and Borneo; *Dictyophyllum*, *Protorhipis*, *Hausmannia*, *Caulopteris*, etc., are closely allied to *Dipteris*, which has five species living in the eastern tropics; Ginkgo—so abundant in the Jurassic—has but a single living representative in China and Japan.

Climatic conditions in Jurassic.—The presence of luxuriant ferns, many of them tree-ferns, equisetums of large size, conifers, the descendants of which are now found in southern lands, all point to a moist, warm, probably subtropical climate, though in late Jurassic time the presence of well-defined rings in the tree trunks of species found in northern areas—King Karl's Land, Spitzbergen, etc.—show that there were beginning to be sharply marked seasons.

Wealden.—Immediately above what by common consent is regarded as the top of the Jurassic, is a series of fresh-water plant-bearing beds that are of quite wide extent in this country, though different names have been applied in the different areas. Thus the lower Potomac of the eastern United States (including the Patuxent and probably Arundel), the Glen Rose beds of the Trinity division of Texas, the Lakota and Cloverly of Dakota and Wyoming, the Kootanie of Alberta and adjacent Montana and extending into the Bighorn Basin of Wyoming, and the Shasta of California, and Kome of Greenland are practically equivalent in age, and correspond most closely in age with the Wealden of the Old World, which is considered to be a fluviatile or lacustrine condition of the lower Neocomian, the lowest member of the Cretaceous. The flora is a comparatively rich one, aggregating between two hundred to three hundred species, and is composed of ferns and conifers with a fair sprinkling of cycads Equisetaceae, ginkgos, etc. It shows a considerable agreement with the Jurassic, a number of species being common to the two, but on the whole its affinity is rather with the Cretaceous.

Cretaceous.—Up to the present point in the geological column the most characteristic and dominant feature of the modern flora—namely the angiosperms—has been absent. In many ways the introduc-

tion of this type of vegetation was one of the most important and far-reaching biologic events the world has known. For many years the flora of the Dakota Group and kindred floras was the oldest angiospermous flora known in this country, but as there are such a host of apparently modern types present, it was presumed that they must have had an ulterior period of development—and such proved to be the case. So far as we now know this flora appears to have had its origin in eastern or northeastern North America, in the Patapsco division of the Potomac series. Although the great majority of the plants found in association in these beds, both as regards species and individuals, still belonged to lower Mesozoic types, such as ferns, cycads, and conifers, we find ancient if not really ancestral angiosperms, and many of the same types are found in beds of approximately the same age (that is Albian) at Circal in Portugal. Although we are here much nearer the origin of the angiosperms than was before known, we are probably still some distance from their actual point of origin, but just where or when that was we do not, and may never know.

No sooner were they fairly introduced, however, than they multiplied with astonishing rapidity and in the upper members of the Potomac series—Raritan—they had become dominant, the ferns and cycads having mostly disappeared and the conifers having taken a subordinate position.

By the close of the Comanchan, or Lower Cretaceous, they had spread as far north as Alaska and Greenland, and a large number of modern genera were established.

Climatic conditions during Comanchan.—The climate over this vast area was certainly much milder than at the present time, for such well-known plants as elms, oaks, maples, magnolias, and many others were growing 72° N., in Greenland and nearly as far north in Alaska. It was at least what we would now call warm temperate.

Upper Cretaceous.—With the inauguration of the Upper Cretaceous the angiospermous flora was in full swing.

On the Atlantic border we have the Magothy, which extended from Maryland over New York, Long Island, and as far as Martha's Vineyard. The flora is a rich one, embracing about one hundred and fifty species.

In the interior, in approximately the same position, is the Dakota,

which has afforded a splendid flora of over five hundred species, and occurs in Kansas, Nebraska, Wyoming, Minnesota, along the international boundary, and some of the same forms as far as central Alaska and south to Argentina.

Of the succeeding members of the Upper Cretaceous the Colorado being largely marine has but a small flora, although in southwestern Wyoming there is a small flora, made up mainly of modern types of ferns (*Gleichenia*), that finds its closest affinity in the Upper Cretaceous of Greenland.

Montana.—As this represents alternations of marine with brackish- and fresh-water conditions we have a larger flora, although the total number of known species probably does not exceed one hundred and fifty. Nothing particularly new was established at this time, the genera there being largely of older formations, though the species are mainly different.

Laramie.—As the uppermost member of the Cretaceous series above the marine Fox Hills, the Laramie has had many vicissitudes of interpretation and was made to include beds now known to belong to the Montana, Arapahoe, Denver, Fort Union, etc. As logically restricted to the original definition of King, the plant-bearing Laramie is confined largely to the Denver Basin of Colorado and adjacent areas to the southward, with the probability of its being demonstrated to exist west of the mountains in Colorado, Wyoming, and New Mexico. As above restricted the Laramie flora comprises about one hundred and twenty-five species, and proves to be remarkably distinct from that of the Montana below as well as from the Arapahoe, Denver, and Fort Union above.

Tertiary.—The close of the Upper Cretaceous saw a considerable percentage of the modern angiospermous types of vegetation fully established, not only in North America but throughout the world, and the ferns, cycads, and conifers relegated permanently to a subordinate position. Certain types of dicotyledons, such, for instance, as magnolias, tulip-trees, sassafras trees, etc., had their maximum development in the Cretaceous, and in the Eocene and subsequent stage were greatly reduced until in the modern flora they are often represented by a few or even single species of very restricted habitat. The most noticeable feature of the Eocene flora, broadly considered,

is the increased number of forms that foreshadow the modern flora, a few, indeed, being still living. As examples of the latter mention may be made of the common sensitive fern (*Onoclea*) and two species of hazelnut (*Corylus*) all of which are now living in eastern North America. In late Cretaceous time the sedges (*Cyperus*, *Carex*, etc.) and grasses (*Arundo*, *Phragmites*) had but a poor representation, but in the late Eocene these groups clearly became more numerously developed both in types and species, and thus apparently made possible the rise and development of the mammalia.

Fort Union flora.—The largest and in many respects most important Eocene flora is that of the Fort Union, which is found over a vast area in the central Canadian provinces, north as far as the valley of the Mackenzie River, and south over central and eastern Montana, the western portions of both North and South Dakota, and at many points in eastern and central Wyoming and northwestern Colorado. It has recently been shown by the writer[1] that the Fort Union, extensive as it was known to be, really embraces more than has commonly been assigned to it. Conformably underlying the beds by some geologists considered as the true Fort Union, occur beds which have often been incorrectly referred to the Laramie, or its equivalents, but which are now regarded as constituting the lower member of the Fort Union formation. This lower member, which includes the so-called "Hell Creek beds" and "somber beds" of Montana, and the "Ceratops beds" of Wyoming, and their equivalents throughout much of the area above outlined, contains a rich flora which is inseparably bound to the flora of the upper member.

The flora of the Fort Union considered as a whole embraces more than five hundred species, and comprises ferns, sequoias, cedars, yews, grasses, sedges, oaks, willows, poplars in great abundance and variety, hazelnuts, walnuts, elms, sycamores, maples, a few figs, an occasional palm, and other more modern types. Whatever the conditions under which this flora grew and was entombed, it is beyond question that the climatic conditions were very different from those now prevailing in the region. But for the presence of palms and an occasional fig it might be presumed that the conditions were not greatly different from those now experienced in Atlantic North Amer-

[1] *Proc. Wash. Acad. Sci.*, Vol. XI, 1909, pp. 179–238.

ica, that is, cool temperate. This flora, which is closely similar to that in north Greenland and the valley of the Mackenzie River, undoubtedly approached from the north. The presence of palms, which are found in the lower parts of the formation, argues, on the basis of present distribution, a somewhat warmer climate, just as the numerous thick beds of lignite throughout the formation argue for extensive, long-continued, moister, marsh conditions.

The flora of the lower member of the Fort Union as at present elaborated embraces about eighty-five species of which number about sixty-five are found in the upper member, while only sixteen of the eighty-five species are found in the Cretaceous below. The uncomformity of the base of these beds together with the differences in the flora, clearly and logically marks the point at which the line is to be drawn between Cretaceous and Tertiary.

In the Mississippian region in Louisiana and Mississippi we have a small Eocene flora (Eolignitic) comprising palms, evergreen oaks, magnolias, laurels, cinnamomums, etc., which appear to be most closely affiliated with small floras in northern New Mexico and adjacent Colorado, the latter in turn being most closely related to much larger post-Laramie floras in the Denver Basin of Colorado. These embrace the Arapahoe with about thirty species, and the Denver with nearly two hundred species, and are believed to be slightly older than the Fort Union—in any event, there are only about thirty species in common.

The Green River formation of upper Eocene age occupies a quite extensive area in central and western Wyoming, and has afforded a flora of some eighty species. It is very distinct from the Fort Union and other Lower Eocene floras, and shows a distinct increase of modern forms.

In the northern Pacific coast region there are a number of Eocene floras, among them that of the Swauk which occurs just east of the Cascade Mountains in Washington. This large flora is entirely different from any other in this country, and consists of types that are for the most part found in Central and northern South America, among them being palms 6 feet in diameter and in layers sometimes a foot in thickness. This shows that the palms were not sporadic or occasional, and indicates, as do many of the other things, that the

climate was mild, probably subtropical. The overlying Roslin formation contains a flora that is almost entirely different from that of the Swauk, and lacking the presence of palms was probably slightly cooler than the underlying formation.

To the northward and covering a vast area in Alaska and well out on the Alaskan peninsula is the Upper Eocene Kenai formation which has afforded a rich flora of oaks, poplars, willows, hazels, walnuts, magnolias, horse-chestnuts, and maples, together with pines, spruces, cedars, and sequoias. This flora is found in British Columbia, and abundantly in Greenland, Iceland, and Spitzbergen, showing that it was of wide extent in similar northern latitudes. It is distinctly a warm-temperate flora. Another Upper Eocene flora is found in the Clarno formation of the John Day Basin, Oregon, and in the Payette formation of western Idaho. It embraces walnuts, hazels, birches, alders, oaks, elms, sycamores, maples, ashes, etc., and is temperate or warm temperate, in character.

Eocene floras in the Atlantic area are of very little importance as thus far developed.

Miocene.—The Miocene flora of North America is relatively not a large one although it comprises probably five hundred species as now known. The deposits occur often in isolated basins, widely separated, and there is usually comparatively little in common between them. A number of the more important areas may be briefly mentioned.

At Brandon, Vermont, in the midst of ancient crystalline rocks, occur small pocket-like deposits of lignite which have yielded large numbers of fossil fruits and a very few poorly preserved leaves. The fruits have been studied by Lesquereux, Perkins, and others, and about one hundred and fifty nominal species described belonging to the genera *Nyssa*, *Hicoria*, *Juglans*, *Bicarpellites*, *Cucumites*, *Tricarpellites*, etc.

At Florissant, Colorado, also in the midst of older rocks, there are small lake-bed deposits which have afforded vast quantities of plant and insect material in an admirable state of preservation. The plants number upward of two hundred species, among them being a great number of very modern types and even including not a few herbaceous forms. This flora as a whole is very unlike anything

found in the region at the present day and apparently finds its closest affinity with the West Indies, though doubtless it also approached originally from the north.

Small deposits containing a Miocene flora have been found in Esmeralda County, Nevada, the Similkameen Valley, and other points in British Columbia, and in the Yellowstone National Park. The so-called Muscall beds of the John Day Basin, Oregon, and extending into central Washington, have yielded a rich flora of about eighty species, among them oaks, maples, poplars, barberry, bread-fruit trees, etc., indicating a warm, moist climate. Associated with the auriferous gravels of California is a flora of about one hundred and twenty-five species, some of which are of very modern appearance, such as *Zizyphus*, *Magnolia*, *Persea*, *Acer*, *Artocarpus*, etc.

Pliocene.—The Pliocene flora of North America is almost a negligible quantity, about the only known locality being the Falls of the Columbia River. It includes species in the genera *Woodwardia*, *Sassajras*, *Sterculia*, etc., and is very closely related to living American species.

Pleistocene.—The Pleistocene flora is better known than the last, yet we are undoubtedly only on the borderland of a knowledge of the plants of this period and their distribution. Small Pleistocene floras are known from New Jersey, Maryland, Virginia, West Virginia, North Carolina, Alabama, New York, Iowa, and Canada. The most extensive exploitation of this flora is that made in Canada in the vicinity of Montreal and Toronto, where Penhallow has been able to make out at least three stages. The species are nearly all living.

CERTAIN VALLEY CONFIGURATIONS IN LOW LATITUDES

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To those who have studied the physiographic features of the tropics, the phenomena described in this paper may be quite familiar, but they do not appear to be well known to the average worker in the higher latitudes, and this is our warrant for publishing what at best are but passing notes. If the phenomena have been critically examined by students of tropical physiography it is to be hoped that they may be stimulated by the imperfections of these notes to publish the fuller truth for the benefit of geologists of the mid-latitudes.

In September, 1906, while riding on the Ferrocarril Mexicano from Esperanza on the high plateau down to Vera Cruz on the Gulf, the attention of the writers was caught by the fact that there was practically no talus at the base of the slopes, even when these slopes were steep and rocky. The peculiar configuration of the valley profiles also arrested attention. Further observations made it clear that these features were prevalent. Preliminary to their discussion, it may be remarked that the Mexican plateau has an elevation of some 7,000 feet above the sea. At its eastern border the tableland ends rather abruptly so that the railroad takes advantage of several deep valleys heading back into the plateau and makes frequent windings on their steep slopes to accomplish its descent to the coastal plain. At first tributaries and then the main stream of the Rio Blanco are followed to the city of Orizaba amid impressive scenery. Between Orizaba and Cordoba the railway passes from the valley of the Rio Blanca to the basin of the Rio Atoyac. Beyond Cordoba, the railway line crosses a series of tributaries of the Rio Atoyac through a region of steadily declining relief. The best expressions of the distinctive configuration of the valleys lie in the upper and steeper portions but in some degree they persist throughout.

Above Orizaba the valley slopes are distinctly steep though not strictly precipitous; and yet in favorable localities the stream possesses

a moderate flood plain, giving the valley a measurably flat bottom. It was observed that wherever the valley floor joins the steep valley sides and might be expected to rise into them with a broad free curve, there is instead almost universally a short sharp curve, almost an angle. There is almost no wide open sweep of the surface from the low slope of the bottoms to the steep slope of the valley sides, such as is so common in the mountainous parts of the United States and in higher latitudes generally, so far as we have seen them. In the higher latitudes the foot of a steep slope of indurated rock of this sort is usually buried beneath a belt of talus and mantle rock which serves to merge the high declivity of the valley side by an open concave swing into the low declivity of the valley bottom. In this tropical Mexican valley the slopes are clean and steep all the way down to the immediate vicinity of the flat bottom into which they turn almost at an angle. On the slopes there is only a very scant sheet of mantle stuff adhering to the rock in place, but yet this mantle supports a luxuriant vegetation. The scree slopes, so familiar in like situations in higher latitudes, are almost entirely absent.

In January, 1909, during a brief visit at Honolulu, we were able to make a hasty study of the Nuuanu Valley which leads up the southern slope of the island of Oahu to the Pali, a striking viewpoint on the backbone of the island. Compared with northern configurations, this valley impressed us as unique in its profiles and, while recalling the Mexican phenomena, was not altogether identical with them. The mountain slopes on either side are exceptionally steep, rising when at their maximum with angles of scarcely less than 60°, as near as the eye could measure; and yet they are generally clothed with vegetation, though the bare rock comes to the surface at many points in the midst of the luxuriant vegetal growth. These slopes are well creased by erosion trenches, giving the valley side a corrugated aspect. Except locally, soil is not abundant in the upper part of the valley, even on the bottoms. There appears to be little or no talus at the base of the slopes, which curve sharply into the valley bottom, much as in the Mexican case. The valley bottom presents a general aspect of planeness, but is rough in detail and usually quite rocky.

One of the noteworthy features of the valley is its peculiar cross-

section. It partakes more nearly of the features of a U-shaped glacial valley than of the typical V-shaped valley familiar to geologists as the product of running water at high gradients; but obviously glacial action has had nothing to do with the sculpturing of this valley. It may be exceptional in this feature, which is possibly dependent on differences in the character of the lava that makes up this part of the island. Unfortunately we were unable to visit any of the other valleys of the island. The lack of talus at the foot of the usually steep slopes was notable and in full consonance with the similar absence in the valleys on the eastern border of the Mexican plateau.

On a railway journey from Yokohama to Kyoto, Japan, in latitude about 35° N., the relation of the broad flats of the lowlands to the higher slopes of the uplands attracted especial attention. As in the preceding cases, their junctions were decidedly more abrupt than is usual in like cases in our northern latitudes in America. The first impression received, due no doubt to inherited geologic habit, favored the assignment of the flats to sea work and the abrupt angle they made with the uplands to the girdling of the sea margin. This view, on closer study, seemed probably erroneous. The plains appeared to be aggradation bottoms, in the main, built up or at least sheeted over by the numerous rivers that emerge from the mountains. The streams across them have notable gradients. The abruptness is thus probably in part constructive, rather than erosional, but is probably also in part erosive and perhaps of the Mexican type.

In South China features of an analogous order were noted. The Si Kiang, or West River, has a long course through the moderately mountainous country which is characteristic of Southern China. From the bottoms that adjoin the river, the hill slopes usually rise promptly and steeply. The mountain range west of Sam Shui in the province of Kwang Tung was estimated to reach 1,000–1,200 feet and perhaps at points 1,500 feet in elevation. Very little talus was seen on its slopes or on any of the mountain slopes. The soil is thin, and under the climatic conditions prevailing here the hills have a limited vegetal covering and are very scantily cultivated. There are, however, lower hills that are often well rounded, with clean, smooth slopes.

From the town of Wuchow in the province of Kwang Si an ascent of a prominent peak, 1,200 feet above the town, gave a commanding view of the general topography of the country about the junction of the Si Kiang and Kwei Kiang. The erosion of this region, working upon an older elevated peneplain of undetermined geologic date, has been very pronounced. Almost everywhere sharp V-shaped valleys with very straight, even-sided slopes prevail. There is prac-

FIG. 1—Bowlders of exfoliation near Kowloon on the Asiatic mainland opposite Hong Kong.

tically no talus or aggradation accumulations until the river level is approached.

In contrast to the above, among the White Cloud hills near Canton, in Kwang Tung, there are extensive accumulations of arkose material. In fact, the solid rock, which is of the granitic type, is almost everywhere buried beneath its own disintegrated products. A similar condition in even more pronounced form was observed at Kowloon on the Asiatic mainland, opposite Hong Kong. In many of the cuts for the new railroad now being constructed from Kowloon to Canton

many feet of disintegrated material were found above the more indurated granite into which the arkose graded slowly. This granite in its upper portion is soft and partially disintegrated. In its lower portion certain "bowlders" or less disintegrated portions in it were being quarried for building purposes. It was not altogether clear whether the "bowlders" are to be regarded merely as residual remnants of a once homogeneous mass left by the unequal progress of disintegration, or whether the whole was a secondary deposit of mixed arkose and bowlders derived from the adjacent hills and once partially cemented together, but which has more recently again resumed its disintegration. There are some reasons for believing that both alternatives are true in different portions of the district. In those localities where deep disintegration prevails, the upper slopes merge into the lower slopes in the gradual, curving way common in higher latitudes.

The main purpose of these notes is to lay emphasis on the relatively sharp angle between the valley sides and the valley bottoms observed in several of these regions of low latitude. In part this feature may, no doubt, be said to be due to the comparative absence of talus at the foot-slope of the valley sides, but this is probably not the whole truth of the matter. The relative absence of coarse talus of a certain kind in low latitudes is recognized as assignable to the absence of freezing temperatures by virtue of which the repeated expansion of water in joint planes, cracks, and pores disrupts the surface rocks and loosens masses which roll to the foot of the slope.[1] The localities named in this paper, except that in Japan, are all within the border of the tropics and this explanation is applicable so far as it goes. Talus piles and scree slopes of the frost type are obviously excluded by the climatic conditions. Bowlders due to exfoliation, which we found so abundant at Kowloon, are probably absent in the localities characterized by thin soils because in these cases the decay proceeded more uniformly and slowly from the surface and was more largely confined to the surface instead of penetrating deeply along the joints and working from them toward the centers of the blocks between the joints. This limitation of action was probably due in turn to the close texture of the rock in the Mexican, Oahu,

[1] J. C. Branner, "Decomposition of Rocks in Brazil," *Bull. G. S. A.*, Vol. VII, 1896, p. 268.

and Kwang Si cases. In the Canton and Kowloon cases granular disintegration prevailed in a marked degree, as is well known to be common in low latitudes, but in these cases the rock was granitic and peculiarly susceptible to this mode of disaggregation. In the Mexican and Oahu localities the rocks were mainly close-textured lavas; in Kwang Si fine-grained sediments, in the main. Under the influence of a warm climate, aided by the tropical vegetation, the rocks of these localities seem to pass into soil on the surface with little detachment of blocks, bowlders, or other coarse material. The rains of these regions are sufficient to keep the soil thin in spite of the vegetal protection and thus to keep the decay working actively on the whole outer surface.

While this seems to explain the nature of the surface and the thin surface mantle, we are not fully persuaded that it altogether explains the abruptness of the change from the side slopes to the valley bottoms. Without attempting to give very cogent reasons for the interpretation, we are disposed to refer this to a mode of hydraulic action which is really normal but which seems abnormal to us because in mid-latitudes it is commonly thwarted by an overburden of detritus. During a rain the water on the slopes grows in amount as the slope is descended and the wash-action is normally greatest at the foot of the slope if the water has not become overloaded with detritus in its descent. The velocity of flow also increases as the slope is descended and this further adds to the erosive power toward the base of the slope. A normal slope should therefore approach more and more to the vertical as it gains in descent. This is almost universally true of the brow and upper part of the slope in all latitudes. Why does it not persist to the bottom? In certain cases it does. Certain mesas, buttes, and outliers, particularly in arid lands, possess essentially vertical sides which reach down either to coarse talus piles or to the horizontal beds of the surrounding region. In some instances there is sapping at the base due to more perishable layers but in other cases there is no sign of this and the cutting at the base appears to be due to the superior volume and velocity of the water rushing down the sides. In these cases the effect is probably correlated with the absence or scantiness of vegetation which when present restrains the rush of the waters. A similar effect is shown in waterfalls, though here differ-

ences of rock resistance usually overshadow it and the joint result has an abnormal expression. Erosion is markedly greatest at the foot of the falls where deep excavation and undercutting are pronounced. A better case for the present comparison is the development of rapids and cascades into vertical falls by the greater erosion at the base of the plunge, even in cases where the rock is essentially homogeneous.

In all these cases the superior erosion due to superior velocity or volume or both is carried only to a certain extent because it meets restraint in the supporting effects of the neighboring rock, and this is probably the key to the solution of that balance of effects seen at the foot-slopes of valleys. While the floods from the slope increase in volume and velocity all the way down the steeper part of the slope, and considered by themselves alone should increase the slope even to verticality, the flat-lying rocks of the valley bottom lend support to the foot of the slope by giving a less proportion of exposure and a higher ratio of adhesion to its surface parts and thus render their removal less easy than they would be in the absence of such support. If this is not quite obvious it may perhaps become clear on picturing a vertical wall formed of spherical granules meeting a horizontal surface of like kind at right angles and noting the individual conditions of the granules. If A represents a granule at the angle, BB′B″, etc., the successive granules above it in the face of the vertical wall and CC′C″, etc., the successive granules in the horizontal face, it is clear that A will be least easily removed because only 90° of its circumference is exposed while 270° is both protected and attached, whereas 180° of the circumference of the B and C granules is exposed and only 180° protected. With equal wear the B and C granules must suffer most and the angle gradually pass into a curve. In a similar way it may be seen that the granules that form a short concave curve are less exposed and have more attachment than the granules of a more open concave curve, or of a plane or convex curve. Each portion of the slope is thus dependent, in a measure, on the support of the other portions and the flat portion of the valley bottom may be said to support the rock at, and near, the angle and cause the development of a curve which represents the working balance between the agencies of erosion and of resistance. By this curve the increasing flood from the slope is

gradually turned from its nearly vertical descent into a more nearly horizontal course.

The meaning of the short curve as distinguished from a longer curve lies in the balance of the co-operating agencies. A good mantle of vegetation when present measurably restrains the plunging waters and somewhat softens the curve of transition. In the absence of vegetation, the abrupt mesa-cliff on the one hand and the vertical or even overhanging falls on the other are liable to develop. The abrupt curve at the foot-slope in the tropical cases described is thus referred to a co-operation of agencies in which (1) the absence of talus-making causes, (2) the prevalence of minute surface decay, (3) the restraint of vegetation, and (4) the concentration of the wash toward the foot-slope are conjoined. This phase of action seems to be prevalent in low latitudes, but not equally so in high latitudes.

THE ANTHRACOLITHIC[1] OR UPPER PALEOZOIC ROCKS OF KANSAS AND RELATED REGIONS

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A recent monograph by Dr. George H. Girty[2] contains certain statements which are so misleading that I desire to briefly call attention to them. In the main they refer to some remarks of mine[3] concerning earlier conclusions published by Dr. Girty relating to the age of the Guadalupian and its correlation with the Upper Paleozoic formations of Kansas.

Dr. Girty has attributed a threefold argument to me[4] which he then proceeds to take up in detail.[5]

In regard to the age of the Guadalupian which is his first point, I quoted *exactly* the words used by Dr. Girty in his two papers and gave them in the order in which they were published.[6] In no way did I attempt to obscure his meaning or mislead the reader concerning it. I *did note* that he had changed quite decidedly from his first opinion concerning the age; but I made no comment and in no way attempted to criticize his opinions. His statement in this last work that I am correlating the Guadalupian with the Upper Permian is erroneous, for I have never expressed *any* opinion concerning the age of the Guadalupian.

In the second place I compared the lists of fossils from the Hueco and Kansas formations published at that time by Dr. Girty, as I

[1] The Anthracolithic is a term proposed by Waagen for the united Carboniferous and Permian systems (*Palaeontologia Indica*, Ser. XIII, Vol. IV, "Geological Results," p. 241). It is here used when speaking of the Carboniferous and Permian systems taken together or as an equivalent of the somewhat indefinite term of Upper Paleozoic.

[2] "The Guadalupian Fauna," *United States Geological Survey, Professional Paper 58*, 1908 [1909].

[3] *Am. Geol.*, Vol. XXXVI, 1905, pp. 156–58.

[4] "The Guadalupian Fauna," *op. cit.*, p. 40.

[5] *Ibid.*, pp. 40–42.

[6] See pp. 156 and 157 of my paper.

stated in my article, and failed to find a single listed species common to the Hueco and Marion formations, the latter occurring next above the Chase stage in Kansas. His statements concerning the correlation between the Kansan and Texan formations I understood to be founded upon paleontologic evidence and my remarks were based simply upon an examination of such published evidence.

In regard to the third point it is true that I understood Dr. Girty's statement in 1905 to refer to the *time* of the deposition of the Capitan, Kansas deposits, and Permian, but as he now explains it he intended to refer especially to their *terminology*. So far as terminology is concerned, as I now understand Dr. Girty and the facts, I should say that the term Guadalupian series essentially as Dr. Girty originally proposed it, *except* that he gave it as "Guadalupian period,"[1] would, for the present at least, be used for the Texan deposits. In Kansas the Upper Paleozoic deposits are known under the names of the Big Blue and Cimarron series. If the Big Blue, Cimarron, and Guadalupian series were deposited during Permian *time* I see no serious objection to putting them in the Permian *period* or system, recognizing this division as co-ordinate in rank with the Carboniferous and other periods of the Paleozoic in accordance with the usage of the majority of geologists who have carefully considered the classification of the Upper Paleozoic. Later studies may show more accurately the relationship of the Texan and Kansan series and make necessary changes in the local classifications. Dr. Beede has suggested the quite different conditions under which these two faunas lived, stating that "one is a cosmopolitan, open-sea, coastal shelf fauna while the other is a more isolated epicontinental sea fauna rather thoroughly separated from its neighbor on the south and perhaps belonging to a different climatic zone."[2]

The assumptions, in connection with the three points noted above, which appear in the work under discussion, I am not responsible for, and therefore they require no further notice.

The expression "Kansas 'Permian'" appears very frequently in the Introduction to "The Guadalupian Fauna" and often it

[1] *Am. Jour. Sci.*, 4th ser., Vol. XIV, 1902, p. 368.

[2] *Jour. Geol.*, Vol. XVII, p. 678.

is used as though it were equivalent to the series of formations for which I have used the designation of Permian system. At this place it is well to state that, so far as terminology is concerned, I consider the Permian division as having the rank of a *period* in time (*system* on the rock scale), and not that of an *epoch* (*series* on the rock scale), in accordance with the usage of most of the recent leading American and European standard manuals of geology.[1] In certain papers published by the United States Geological Survey or with its permission I have used the name Permian with the taxonomic rank of an *epoch* or *series*, because required to do so by the rule of the United States Geological Survey which states that "in the Carboniferous, Permian, Pennsylvanian, and Mississippian" are series "now recognized as applicable to North America."[2] Dr. Girty uses the term "Permian epoch"[3] in accordance with the rule of the United States Geological Survey. If this fact be kept in mind it will explain some of the differences in correlation between the papers of Dr. Girty and my own.

Concerning the lower limit of the Permian system in Kansas I wrote in 1895:

> If it be considered better to put all the beds in either the Carboniferous or Permian system, it might be just as well to refer the deposits generally called Permo-Carboniferous to the Permian. If such correlation be agreed upon, then, in Kansas, the line separating the Cottonwood and Neosho formations would become the line of division between the Carboniferous and Permian systems.[4]

Furthermore, on pp. 795, 796 I continued as follows:

> Consequently we would refer the Wabaunsee and Cottonwood formations to the Upper Coal Measures. The Neosho and Chase formations are transitional

[1] See Chamberlin and Salisbury, *Geology*, Vol. II, 1906, p. 619; Scott, *An Introduction to Geology*, 2d ed., 1908, p. 637; Geikie, *Text-Book of Geology*, 4th ed., 1903, Vol. II, p. 1063; De Lapparent, *Traité de géologie*, 5th ed., Vol. II, 1906, p. 752; Suess, *The Face of the Earth* (*Das Antlitz der Erde*), Sollas' translation, Vol. II, 1906, p. 249 (*La Face de la terre*, Margerie's translation, Tome II, 1900, p. 407); Kayser, *Lehrbuch der Geologie*, 3d ed., II. Teil, 1908, p. 256; Credner, *Elemente der Geologie*, 9th ed., 1902, pp. 367, 490; Dannenberg, *Geologie der Steinkohlenlager*, erst. Teil, 1909, p. 42; Toula, *Lehrbuch der Geologie*, 1900, pp. 200, 231; Neumayr, *Erdgeschichte*, Vol. II, 1890, p. 199; Frech in *Lethaea geognostica*, Theil I, "Lethaea palaeozoica," 2. Bd., 3. Lief., 1901, p. 453; Koken, *Die Leitfossilien*, 1896, p. 550.

[2] *Twenty-fourth Ann. Rept.*, 1903, p. 27.

[3] "The Guadalupian Fauna," *op. cit.*, p. 42. [4] *Jour. Geol.*, Vol. III, p. 793.

from the Upper Coal Measures to the Permian, as first defined by Murchison for Russia, and belong to the division which has generally been called Permo-Carboniferous, in this country. In accordance with the views of the majority of present European geologists familiar with this problem it is probably better to include the Permo-Carboniferous rocks of Kansas in the Permian series. . . . . The Marion formation belongs to the undoubted Permian and contains only fossils which are characteristic of that series.

In Russian geological literature the term Permo-Carboniferous frequently occurs, the lower terrane of which is the Artinsk and the upper the Kungur; but the later standard European works on geology refer these terranes to the Permian.[1] I have followed them in putting the Kansas Permo-Carboniferous in the Permian. Dr. Kayser in the last edition of his *Formationskunde* states that the Permian formation of the interior Russian-Uralian district is divided in the following manner:

Tartarian stage Russian Zechstein (limestone) Kupfer sandstone Lower Red Beds	Permian in the strict sense.
Kungur stage Artinsk stage	Permo-Carboniferous of Russian geologists.[2]

Dr. Kayser has written me recently that:

As far as the Artinsk formation is concerned, I still entertain the same opinion as at the time of the writing of the last edition of the *Formationskunde*, i. e., I look upon it as the *base of the Permian*. The Ammonite fauna of the Artinsk, which varies considerably from the Carboniferous, and the flora seem to me in this respect decidedly significant.[3]

The line of division between the Carboniferous and Permian I always considered a debatable one. In my paper of 1902 it was thought that the evidence favored drawing it at the top of the Neosho member of the Garrison formation or at the base of

[1] Geikie, *Text-Book of Geology*, 4th ed., Vol. II, 1903, p. 1077; De Lapparent *Traité de géologie*, 4th ed., Vol. II, pp. 968, 993; Kayser, *Lehrbuch der Geologie*, 3d ed., pt. II, 1908, p. 290; Frech, *Lethaea geognostica*, Theil I, "Lethaea palaeozoica," 2. Bd., 2. Lief., 1899, chart opposite p. 394, and 3. Lief., 1901, pp. 493–99; Credner, *Elemente der Geologie*, 9th ed., 1902, p. 517; Toula, *Lehrbuch der Geologie*, 1900, pp. 219, 238.

[2] *Lehrbuch der Geologie*, Pt. II, 1908, p. 290.

[3] Letter of November 11, 1909.

the Wreford limestone of the Chase stage.[1] This agreed quite closely with the later correlation of Dr. Tschernyschew who drew the line separating the homotaxial equivalents of the Russian Upper Carboniferous and Permo-Carboniferous at the base or in the lower part of the Chase stage. The following is a translation of Dr. Tschernyschew's views: The Neosho beds, and possibly also the lower part of the Chase, appear analogous to the Russian Schwagerina horizon [the Schwagerina beds form the upper division of the unquestioned Upper Carboniferous of Russia, just below the Artinsk] and the remainder of this, as well as the Marion beds, one must consider as homotaxial with the Russian Permo-Carboniferous and lower Permian. Finally, the Wellington and Cimarron beds may correspond to the lower red-colored Permian in eastern and northern Russia.[2]

More accurate information concerning the horizon of certain vertebrates described by Dr. Williston from southern Kansas led the writer in 1907 to suggest that perhaps the Cottonwood limestone at the base of the Garrison formation, which is nearly the same as the first provisional line, "is really nearer the line of division between the Pennsylvanian and Permian than the Wreford limestone at its top."[3] This line is from 140 to 145 feet lower than the base of the Wreford limestone and about 14 feet lower than the line suggested in my first paper on the classification of these rocks in 1895.[4]

When my earlier papers were written no fossils had been found in the Cimarron series or Red Beds and in 1897 I stated that "the correlation of these rocks with either the Triassic or Permian is a matter of uncertainty."[5] In 1906 Doctors Gould and Beede published an account of the discovery of Permian fossils in a sandstone west of Alva, Oklahoma, the stratigraphic position of which was given

[1] *Jour. Geol.*, Vol. X, Chart of "Classification of the Upper Paleozoic Formations of Kansas," opp. p. 718.

[2] *Mém. comité géologique*, Vol. XVI, No. 2, 1902, pp. 392, 393 of Russian text and p. 703 of German text. For translation see *Am. Geol.*, Vol. XXXVI, 1905, p. 154, and Schuchert in *Am. Jour. Sci.*, 4th ser., Vol. XXII, 1906, p. 38.

[3] *Jour. Geol.*, Vol. XV, p. 823.

[4] *Ibid.*, Vol. III, p. 800.

[5] *Univ. Geol. Surv. Kansas*, Vol. II, p. 92.

as in the Red Bluff sandstone[1] which occurs well toward the top of the Cimarron series as found in Kansas. Finally, in 1907, Dr. Beede described a fauna from Dozier, in the Panhandle of Texas, which occurs stratigraphically, according to Doctors Beede and Gould, in the Quartermaster division of the Oklahoma formations which they state "is the highest formation in the Red Beds, and the fossils came from well up in this formation."[2] According to these geologists the Quartermaster division occurs entirely above the top of the Cimarron or Red Beds as found in Kansas. Dr. Beede described the faunas from the Whitehorse sandstone and the Dozier beds under the title of "Invertebrate Paleontology of the Upper Permian Red Beds of Oklahoma and the Panhandle of Texas" and said:

> These collections are of great importance, as they furnish the final evidence that the Red Beds, below the Dockum beds, of the Oklahoma-Panhandle region are Paleozoic in age. . . . . The faunas are somewhat heterogeneous as to origin. Some of the species seem to be directly derived from the Kansas Permian or Pennsylvanian, while others, as pointed out in the discussion of the species, are derived from the European Permian, especially that of Russia.[3]

In the lower part of the Enid division at a horizon corresponding with the upper part of the Wellington shales of Kansas,[4] which is the highest formation of the Big Blue series, near Nardin and Orlando, Oklahoma, vertebrate fossils were found. The specimens from Orlando were studied by both Doctors Williston and Case and a preliminary list was furnished by Dr. Williston who wrote Dr. Gould as follows concerning it: "Altogether you see that these fossils point unmistakably to the Permian."[5] Dr. Case furnished a report on these fossils for publication and in conclusion said:

> The result of the determination of these fossils has been to settle the long mooted question of the age of the Red-beds. . . . . The Red-beds of Oklahoma,

[1] Beede, *Am. Geol.*, Vol. XXVIII, July, 1901, pp. 46, 47. The fauna was first described by Dr. Beede in the "Advance Bulletin of the First Biennial Report of the Geological Survey of Oklahoma," April, 1902. Later it was more fully described by the same author in the *Kansas Univ. Science Bulletin*, Vol. IV, March, 1907, pp. 115–72, Pls. V–IX; Gould, *Jour. Geol.*, Vol. IX, July, 1901, pp. 337–41.

[2] *Kansas Univ. Science Bull.*, Vol. IV, p. 141. [3] *Ibid.*, pp. 115, 142.

[4] Beede, *Kansas Univ. Science Bull.*, Vol. IV, 1907, p. 138; Gould, *Jour. Geology*, Vol. IX, 1901, p. 339.

[5] *Sec. Biennial Rept.*, Dept. Geol. and Nat. Hist., Territory of Oklahoma, 1902, p. 60.

then, or at least the members as high as the Greer formation [the base of which is near the top of the Kansas deposits] are of Permian age.[1]

Fossil plants were collected in the Wellington shales[2] in the southern part of Dickinson County, which were studied by Dr. Sellards who wrote as follows concerning them:

There are, in the collections so far made, some twenty-six or twenty-seven determinable species, distributed in fourteen genera. The plants indicate unmistakably the true Permian age of the formation in which they are found. Many of the species are characteristically Permian, and only a very small proportion of the species identical with Upper Carboniferous species.[3]

Part of this material was communicated to the National Museum by Dr. Sellards and examined by Mr. David White of the United States Geological Survey, who wrote as follows regarding it:

If the composition of the entire flora proves to be of so young a character as the material described or placed in my hands by Mr. Sellards, his conclusion that the beds are of so late date as the Lower Permian will appear to be fully justified. . . . . However, such pteridophytic material as has come to me for examination is more nearly typical and characteristic of the Permian than any flora that I have yet seen from another formation in the United States. If the plants preliminarily listed above are representative of the plant life of the Upper Marion or the Wellington formation, the flora of these beds is probably of a date fully as late as the earlier of the floras generally referred to the Permian in western Europe. In any event a flora containing these species can hardly be older than the topmost Carboniferous, or transitional from the Upper Carboniferous to the Permian.[4]

In January, 1903, Dr. Sellards wrote me as follows:

The fossil plants in my opinion support your belief in the existence of true Permian in Kansas (below the Red Beds). The flora of the Marion (or Wellington) differs specifically almost *in toto* from that of formations as low down as the Lawrence shales [which occur in the Pennsylvanian near the top of Professor Haworth's Douglas stage] and indicates as I have already stated (*Kans. Acad. Sci.*, 1900; *Kans. Univ. Bull.*, Vol. IX, Jan., 1900) a lower Permian age. The plants in this case are pretty conclusive and the genera and species are identical with or most closely related to those of the lower Permian of Europe.[5]

[1] *Ibid.*, p. 68.

[2] Stratigraphic identification by Dr. J. W. Beede, see *Am. Jour. Sci.*, 4th Ser., Vol. XXVII, 1909, p. 169.

[3] *Trans. Kansas Acad. Sci.*, Vol. XVII, 1901, p. 209.

[4] *U. S. Geol. Surv., Bull. 211*, 1903, p. 117.

[5] Letter of Jan. 12, 1903, and see *Am. Geol.*, Vol. XXXVI, p. 149.

Dr. Sellards also found well-preserved insects associated with the plants in the Wellington formation of Dickinson County which he contrasted as follows with those from near Lawrence, Kansas:

> The insects from the Marion seem on the whole very different from those of the Lawrence shales and other Coal Measure deposits. . . . . These collections [of fossil plants from the Wellington] have since been increased and it may now be said with a good deal of confidence that, although a few species have survived from the Upper Coal Measures, the Marion [Wellington] contains on the whole a distinctly Permian flora. The marked change in the insect fauna in passing from the Lawrence shales to the Marion [Wellington] formation is therefore paralleled by the plant evolution.[1]

This fairly full summary of the conclusions of the various paleontologists who have carefully studied the fossils from the deposits under consideration in Kansas and Oklahoma, previous to the publication of my last note on this subject in December, 1907,[2] is given in order to show the limits of the Permian as indicated by fossils and that, with the exception of Dr. Girty,[3] all agreed in referring them to the Permian. It is believed by the writer that the above evidence warrants the provisional correlation of these Kansas deposits with the Permian, until it is shown by someone that such correlation is erroneous, and that the Permian system extends to the top of the Cimarron series or Red Beds as found in Kansas. References to and quotations from the works of various European geologists who have correlated these deposits with the Permian have been given in earlier publications. Finally, it is to be noted that the fossil evidence now in hand indicates that the base of the Permian system in Kansas begins as low as the Cottonwood limestone, or perhaps a little lower, and that the succeeding rocks in Kansas to the top of the Red Beds belong in this system, *because* still higher deposits to the south in Oklahoma and the Panhandle of Texas contain a Permian invertebrate fauna as described by Dr. Beede. The above-defined deposits are those which I call the Permian system and for which I have accepted the division into two series, viz., the Big Blue and Cimarron, proposed by Professor Cragin in 1906.[4]

[1] *Am. Jour. Sci.*, 4th ser., Vol. XVI, 1903, pp. 323, 324.

[2] *Jour. Geol.*, Vol. XV, p. 822.

[3] *Ibid.*, Vol. X, 1902, p. 723; *U. S. Geol. Surv., Bull. 211*, 1903, pp. 74–77.

[4] *Colorado College Studies*, Vol. VI, March, 1896, pp. 3, 5, 18.

Dr. Girty states:

> In the first place, here and elsewhere in speaking of the Kansas "Permian" I refer to the Chase and Marion formations, but not to any of the higher beds, as I believe that the only practical method of correlating terranes so widely separated as those of Kansas and Russia is by paleontologic evidence; and since the evidence of invertebrate paleontology only is that which I am in a position to understand and weigh, it is natural that any statement of mine must apply to that portion of the Kansas section where invertebrate fossils are found, and cannot consistently apply to formations overlying the Marion, where invertebrate evidence appears to be absent. Furthermore, unless otherwise indicated, in speaking of the Permian I refer primarily to the Russian Permian exclusive of the underlying Artinsk or Permo-Carboniferous.[1]

It will be seen on comparison with what I have given above that according to Dr. Girty's definition what he has discussed as the "Kansas Permian" includes only a *part* of the deposits which the Kansas geologists refer to that system. In other words, it does not fully represent the Big Blue series and none of the Cimarron series is included; consequently this fact should be kept in mind when considering what he has said in reference to the "Kansas Permian." The horizons at which the invertebrate fossils were found in Oklahoma and northern Texas have been accurately fixed in relation to the Kansas deposits by stratigraphic work from Kansas to Texas, so that the consideration of their faunas is entirely appropriate in determining the age of the Kansas deposits. The Whitehorse sandstone fauna was known to Dr. Girty at the time he wrote this monograph, since he refers to it on p. 48.

There is a difference of opinion among European geologists as to whether the Artinsk, which is the lower division of the Permo-Carboniferous of the Russian geologists, should be included in the Permian. I have always recognized this fact; but it has appeared to me that the usage of the majority of those best acquainted with the subject favored its reference to the Permian. An extract from the work of Dr. Carl Diener, the accomplished professor of paleontology in the University of Vienna, who has so fully described the Permo-Carboniferous and Permian of the central Himalayas of India, and who has clearly stated the views of the two noted Russian geologists who favor the separation of the Permo-

[1] "The Guadalupian Fauna," *op. cit.*, pp. 46, 47.

Carboniferous from the Carboniferous and Permian systems, is important in this connection:

Karpinsky and Tschernyschew, two authors, to whom the most detailed studies of the Artinskian fauna are due, strongly advocate the distinction of the permocarboniferous from carboniferous and permian systems, and are decidedly averse to uniting it with either the one or the other. Tschernyschew especially strongly combats the view of the majority of geologists who proposed to unite the permocarboniferous with the permian, as a lower division of the system. According to him a separation of the permocarboniferous from the permian system is demanded by the general aspect of the fauna, in which the carboniferous types greatly predominate, chiefly among the brachiopoda. If it ought to be united either with the carboniferous or permian system, in spite of its distinctly intermediate position, it must necessarily be placed in the former, on the strength both of the carboniferous character of its fauna and of historical priority, since the Artinskian sandstone had been correlated with the carboniferous millstone-grit of western Europe by Sir Roderick Murchison, who first introduced the name of permian.

Against the first argument the objection may be raised that notwithstanding the prevalence of carboniferous types in the Artinskian fauna, the latter "marks a very important moment in the history of development of organic remains, namely, the first appearance of true ammonites with complicated sutures." Nor is the large percentage of carboniferous types in the Artinskian fauna an astonishing fact, in view of the absence of any break in the sequence of marine beds from the upper carboniferous to the true permian strata. . . . . Bearing in mind the gradual passage from an upper carboniferous to a permian fauna through the intermediate group of rocks, the question to be answered is, which consideration is of the greater importance in defining the boundary between the two systems, the appearance of a new group of cephalopoda, which become of an unparalleled stratigraphical value in Mesozoic times, or the presence of a belated fauna, composed of forms which are generally not well adapted for the characterization of narrowly limited horizons.

The majority of geologists have decided in favor of the first alternative. Gümbel, Krasnopolsky, Kayser, Waagen, Credner, Munier-Chalmas and A. de Lapparent, Frech—to enumerate only a small number among them—are unanimous in regarding the permocarboniferous as the lowest division of the permian system.

A discussion of the permocarboniferous problem from a historical point of view leads to a similar result. This side of the question has been especially treated by Frech, whose reasoning I consider to be entirely justified.[1]

[1] "The Permocarboniferous Fauna of Chitichun," No. I, *Mem. Geol. Surv. India*, ser. XV, "Himálayan Fossils," Vol. I, Pt. 3, 1897, pp. 87–89. This quotation may also be found in an article by Professor Schuchert in *Am. Jour. Sci.*, 4th ser., Vol. XXII, 1906, pp. 143, 144.

Dr. Diener's account of the correlation of the Upper Paleozoic formations of central Europe with those of Russia is also interesting. The professor wrote as follows:

> In the Rhenish regions, where the sequence of terrestrial and lacustrine plant-bearing strata of this epoch is most complete, the true coal measures come to an end with the Ottweiler Schichten, whereas the following series of rocks, comprising the Cuseler and Lebacher Schichten, have been united in a lower division of the permian system by Gümbel. In the Carnian Alps plant-bearing beds, containing a rich flora of the Ottweiler Schichten, alternate with Fusulina limestones, which have been proved by Schellwien to be homotaxial with Nikitin's Gshelian stage in Central Russia. As has been noticed by Geyer, this alternating series of dark Fusulina limestones and plant-bearing beds is conformably followed by a compact mass of white Fusulina limestones (Trogkofelkalk) containing *Spirifer supramosquensis* Nikitin, which must be correlated with the topmost carboniferous Fusulina limestones (Schwagerina horizon) of the Ural Mountains. The homotaxis of the Ottweiler Schichten and of the Carnian Fusulina limestone, which itself corresponds in age to the uppermost carboniferous beds of Central Russia (Gshelian stage) and of the Ural (Cora horizon, and Schwagerina horizon), apparently requires the boundary line between the two systems to be drawn immediately above the Schwagerina limestone of the Ural and Timan, and below the Artinskian stage.[1]

Professor Diener still believes that the Artinsk belongs in the Permian, as may be seen in the following quotation from a recent letter:

> The Artinskian stage of Russia I still consider as forming the lowest stage of the permian system. Its cephalopod fauna differs decidedly from any which has been found in the upper carboniferous rocks of the Ural. As a boundary line must necessarily be drawn between the two systems, this line—artificial as it is—should be drawn at the base, not at the top of the Artinskian stage.[2]

In all my references, however, to the correlations of the Kansas deposits with those of Europe by European geologists, I have given exactly the name of the European division with which they made correlation and if it were with the Artinsk or Permo-Carboniferous it was so stated.

On page forty-eight Dr. Girty states that "Tschernyschew correlates part but not all of Prosser's 'Permian' with the Artinsk"; while on the following page he says, "if the Kansas 'Permian'

[1] *Ibid.*, p. 89.

[2] Letter of November 24, 1909.

is Artinsk, as Tschernyschew believes." The translation of Dr. Tschernyschew's statement is as follows:

> The Neosho beds and possibly also the lower part of the Chase, appear analogous to the Russian Schwagerina horizon and the remainder of this as well as the Marion beds one must consider as homotoxial with the Russian Permo-Carboniferous and lower Permian. Finally, the Wellington and Cimarron beds may correspond to the lower red-colored Permian in eastern and northern Russia.[1]

The following correlation table of the Russian and American formations, omitting the column for California, Nevada, Utah, and Colorado, follows Dr. Tschernyschew's general discussion of these deposits:[2]

Ural and Timan	Texas and Arkansas	Kansas, Nebraska, Iowa, Missouri
Artinsk deposits	Wichita and Clear Fork beds	Marion Beds
Schwagerina horizon	Albany and Cisco beds	Chase beds Neosho beds
Cora horizon	Canyon and Strawn beds	Missouri series and Cottonwood beds of Kansas and Nebraska Wabaunsee beds Oread limestone and Osage shales of Kansas
Omphalotrochus horizon		Series from the Garnet to the Oswego limestones in Kansas. Des Moines beds in the state of Missouri

It is to be remembered that Dr. Tschernyschew believes in the separation of the Permo-Carboniferous from the Carboniferous and Permian systems. He places the Artinsk in the Permo-Carboniferous and directly overlying the Artinsk is the dolomitic limestone (Kungur) the base of which marked the lower limit of Murchison's original Permian, according to some authors, while others make its top the base. The Permo-Carboniferous of the Russian geologists is generally

[1] *Mém. comité géologique*, Vol. XVI, No. 2, 1902, p. 703. The original is as follows: "Die Neosho-Schichten und vielleicht auch die untere Partie der Chase-Suite erscheinen dem Schwagerinen-Horizonte Russlands analog und der Rest von dieser, sowie die Marion-Schichten muss man als dem russischen Permo-Carbon und unterer Perm homotaxal ansehen. Die Wellington- und Cimarron-Schichten endlich dürften der unteren roth gefärbten Perm-Suite im Osten und Norden Russlands entsprechen."

[2] *Ibid.*, p. 395 of Russian and 706 of German text.

composed of the Artinsk (CPg) and the superjacent dolomitic limestones (CPc).

Hans v. Staff has recently published the following table of the Russian Upper Carboniferous *Fusulina*-bearing horizons:[1]

Permo-Carboniferous	CPg[2]	Arta [Artinsk] stage		Lower Rothliegende	Lower Dyas
	C_5^2	Schwagerina horizon		Horizon of *Schwag. princeps*	Upper upper Carboniferous
Upper Carboniferous	C_5^1	Cora horizon		Bed of *Spirifer supramosquensis*	Middle upper Carboniferous
	C_4^1b	Cora limestone and oölite with *Omph. Whitneyi*	*Omphalotrochus* horizon (Bed of Gshel)		
	C_4^1a	Limestone with *Spir. Marcoui*			
Middle Carboniferous	C_3	Transgression in the Timan	Moskau bed	Bed of *Spirifer mosquensis*	Lower upper Carboniferous

Dr. Girty criticizes the statements which I have made concerning certain fossils; but as the invertebrate fauna, exclusive of the insects, is being critically examined by Dr. J. W. Beede who has studied it more thoroughly than anyone else, I will not devote any particular space at present to the consideration of this part of the subject, with the exception of calling attention to some facts which support my identification of the Kansas specimens as *Fusulina*.

Dr. Girty has written as follows:

> It might also be pointed out that just below the Artinsk a zone in the Russian section is characterized by a profusion of *Schwagerina* occurring in association with Fusulinas. Now *Schwagerina* has never been reported from the Mississippi Valley, while I have recently[2] offered reason for believing that the Fusulinas of the Kansas section, if they do not belong to a different genus, at least show important differences from the typical Fusulinas. These facts seem to destroy Mr. Prosser's argument so far as this item of evidence is concerned. At the same time these very forms furnish more stable evidence looking somewhat in the same direction.[3]

[1] *Palaeontographica*, Vol. LV, 1908, p. 140.

[2] *Am. Jour. Sci.*, 4th ser., Vol. XVII, 1904, pp. 234–40.

[3] *Ibid.*, pp. 43, 44.

It is quite true that Dr. Girty wrote me when the manuscript of the Cottonwood Falls folio was being revised, stating "that the common so-called *Fusulina cylindrica*, or *Fusulina secalica*, of the Mississippi Valley is not congeneric with the real *Fusulinas* of Russia, or at any rate belongs to a distinct subgenus."[1] It seemed to me that the specimens in the Cottonwood limestone and associated formations of Kansas were *Fusulina*, which I stated to Dr. Girty. He answered as follows:

> I am sorry that you do not agree with me in the matter of Triticites, but it matters less what you think or what I think than what the consensus of Paleontologic opinion decides. I feel confident Triticites will be accepted as a good subgenus and probably as a genus. Nevertheless I would be glad to convince you and am sending a couple of examples of Fusulina. That from 2,931 shows the fluted partition wall when viewed against its surface. That from 2,957 shows the edges of the partition walls and the pattern which their undulating edges make in conjunction with one another. You doubtless have good specimens of Triticites in your own collection. You will observe that in the latter the partition is quite straight, and if you bear in mind the differences upon which other genera are established among the foraminifera you will feel a little more like accepting Triticites. . . . . Please return the specimens which are from western Texas. They show the same structure as typical Fusulina from Russia, but are much more elongate.[2]

These Texas specimens were compared with some from the Cottonwood limestone of Kansas and specimens of the latter were found with fluted partition walls essentially the same as in the former, according to my observation. I also wrote Dr. J. W. Beede concerning these Kansas specimens, who answered that "the Cottonwood limestone specimens are true *Fusulinas*"[3] and later in answer to my direct question said that "the Cottonwood specimens *certainly* have fluted septa."[4]

The literature also supported the above identification and as far back as 1866 Dr. H. B. Geinitz identified specimens which had been collected by Jules Marcou from Plattsmouth, Nebraska, as *Fusulina cylindrica* Fischer and *F. depressa* Fischer.[5]

In 1872 Meek published the following paragraph under his descrip-

[1] Letter of April 13, 1904.
[2] Letter of May 9, 1904.
[3] Letter of May 11, 1904.
[4] Letter of May 14, 1904.
[5] "Carbonformation und Dyas in Nebraska" (*M. d. K. Leop.-Carol. Akad. d. Naturf.*), p. 71, Pl. V, Figs. 5*a*, *b*, and *c*, and p. 72, Pl. V, Figs. 6*a*, *b*, and *c*.

tion of specimens from the Coal Measures of southeastern Nebraska which he identified as *Fusulina cylindrica* Fischer:

> In following the general practice of referring this to the Russian species, I am not only governed by comparisons with figures and descriptions of the latter, but I have had an opportunity to make direct comparison with specimens of *F. cylindrica* kindly sent to me by Colonel Romanowski, of the Russian mining-engineers's department, from the Ural Mountains. It is true these Russian specimens are not in a condition to show very clearly in polished sections the minute details of their internal structure under the microscope, but so far as I have been able to determine from the comparison, they seem to agree well with the American form.[1]

Orestes H. St. John collected specimens from many of the Kansas horizons which he sent to Möller who carefully studied them and referred them to European species. As for example, he referred with a ? mark *Fusulina cylindrica* Meek, Neb. 1872, Report, pp. 140, 141, Pl. 1, Fig. 2, to *Fusulina montipara* Ehren,[2] and in the same way Figs. 3*a* and 3*b*, Pl. V, and Figs. 8*a* and 8*b*, Pl. VII, of the Meek and Hayden report were considered with a ? mark as synonyms of *Fusulina Verneuili* Möller.[3] Later he accepted the species *Fusulina ventricosa* Meek and Hayden for part of the Kansas valley forms; and other specimens, which he stated were very well figured in the Meek and Hayden reports (Pl. II, Fig. 1; Pl. V, Figs. 3*a* and 3*b;* Pl. VII, Figs. 8*a* and 8*b*, and *Palaeontology of the Upper Missouri*, 1865, Pl. I, Figs. 6*a*–6*c*), he considered a variety of the above-mentioned species and denoted it as *F. ventricosa* Meek and Hayden var. *Meeki* Möller.[4] Then follows a list of localities in the Kansas valley from which specimens of these two forms were sent him by Professor Orestes St. John. *Fusulina ventricosa* var. *Meeki* he stated is distributed throughout all the strata from which St. John sent him specimens, and he noted it particularly in those specimens with the numbers 1–5 and 11.[5] This statement is accompanied by a note, apparently furnished by St. John, which states that "No. 11 is in the Kansas valley, bed No. 28, Manhattan, Kan. This is the highest or most recent horizon, in which *Fusulina* has been found and is near the base of the so-called Permo-Carboniferous of American

[1] *Final Rept. U. S. Geol. Surv. Neb. and Adjacent Territories*, p. 140.

[2] *Mém. Acad. Imp. Sci. St. Pétersbourg*, Ser. VII, Vol. XXV, 1878, p. 62.

[3] *Ibid.*, p. 64.

[4] *Ibid.*, Vol. XXVII, 1879, p. 5.

[5] *Ibid.*, p. 6.

geologists. This bed is 330 to 430 feet above No. 95 of the Kansas valley section."[1]

Dr. E. Schellwien has recently stated in his description of *Fusulina montipara* (Ehrbg.) Möller that: those portions of Möller's treatise, which refer to the American forms, are to be stricken out.[2] A footnote on the same page contains the statement by Schellwien that: Möller apparently was in doubt, whether or not the American Fusulinas were identical with *F. montipara*. In the appendix (which the writer has not seen) he has later expressed himself as being opposed to a union of the forms.

Dr. Schellwien has also stated that in America a *Fusulina* occurs in Iowa, Indiana, and Nebraska which is described from there under the name *Fusulina cylindrica* and departs so little from *F. regularis* Schellwien that they probably must be united.[3] The last-named species was reported by Dr. Schellwien from the Upper Carboniferous of the Karnic Alps. In his later work he has again referred to the close relationship existing between the eastern Alpine *Fusulina regularis* and the widely distributed group of North American *F. secalis* [*secalica*] Say.[4]

Dr. Schellwien further said that the so often cited *Fusulina cylindrica* in all probability does not occur in America. The genuine *Fusulina* before me from Iowa, Illinios, Indiana, Missouri, and Nebraska all belong to one and the same group, yet these forms exhibit only a small part of the American Fusulinas.[5] The opinion that *F. cylindrica* Fischer does not occur in the United States is stated more positively in Schellwien's last work on the Fusulinas where he said: The American Fusulinas which will be described in a later number show no relationship whatever to *F. cylindrica*.[6]

Dr. Beede first called attention to the description of the American forms by Say in 1823 under the name of *Miliolites secalicus*, fourteen years earlier than the description of the genus *Fusulina* and European species of *F. cylindrica* by Fischer v. Waldheim, and revived

[1] *Mém. Acad. Imp. Sci. St. Pétersbourg*, Ser. VII, Vol. XXVII, 1879, pp. 5, 6.

[2] *Palaeontographica*, Vol. LV, 1908, p. 185.

[3] *Ibid.*, Vol. XLIV, 1897, p. 251.

[4] *Ibid.*, Vol. LV, 1908, p. 183, n. 4.

[5] *Ibid.*, Vol. XLIV, p. 280, n. 3.

[6] *Ibid.*, Vol. LV, 1908, p. 162, n. 3.

Say's name as *Fusulina secalica* which he used in general for the Kansas specimens which had heretofore been called *F. cylindrica*.[1]

From Hooser, Cowley County, in southern Kansas and probably from the Neva limestone, which occurs some 40 feet below the horizon of the Cottonwood limestone, Erich Spandel described seven genera and nine species of Foraminifera. One of these he identified as *Fusulina* cf. *regularis* Schellwien and stated that the chambers correspond the best with *F. cylindrica* Fischer, modified by Möller, and *F. regularis* Schellwien. Since the outside, however, corresponds to the last species, so I believe, it is identical with the same or quite nearly related.

Those specimens described and figured by H. B. Geinitz from the Permo-Carboniferous of Plattsmouth, Nebraska, under the names of *Fus. cylindrica* Fischer, and *Fus. depressa* Fischer, appear to be identical with those here discussed.

Two of the new species of Foraminifera were named *postcarbonica* and Spandel wrote as follows regarding the correlation of this horizon:

> The genus *Monogenerina* is new which appears to be restricted to the Permo-Carboniferous. The other genera are already known to us from the Carboniferous. The presence of *Fusulina* gives the fauna a more Carboniferous character, the frequent appearance of the Nodosaridæ with three species refers the same, however, to the lower limit of the Permian.[2]

In 1903 Professor J. A. Udden reported "great numbers of *Fusulina cylindrica*" in the calcareous rocks of the Missourian series in Fremont and Mills counties in southwestern Iowa, bordering on Nebraska, which was stated to be interesting "as furnishing an additional item for consideration in correlating the uppermost members of the Carboniferous of America with those of Europe, where the same forms occur at about the same level in the geological scale."[3]

The above observations and statements appeared fairly conclusive; but in order that there might be no mistake a specimen was sent

[1] *Univ. Geol. Surv. Kansas*, Vol. VI, 1900, p. 10.

[2] *Abhand. d. naturhistorischen Gesellschaft in Nürnberg*, 1901, p. 19.

[3] *Jour. Geol.*, Vol. XI, p. 284. For the geological sections and various lists of fossils containing *F. cylindrica* see Professor Udden's report on the geology of these two counties in Vol. XIII, 1903, of the *Iowa Geological Survey*, pp. 137 ff.

over to the late Dr. E. Schellwien at the University of Königsberg, who was generally considered as the leading authority in the world upon the Paleozoic Foraminifera. After examining the specimen he wrote me a letter which has been translated as follows by Berthold A. Eisenlohr, associate professor of the Germanic languages and literatures in the Ohio State University:

BERNSTEINSAMMLUNG DER UNIVERSITÄT 18/7, '04
KÖNIGSBERG I. PR.

MY DEAR COLLEAGUE:

I have examined the Fusulinas, which you were so kind as to send me for investigation, after making thin sections of them. They are genuine Fusulinas of the *Fus. regularis* Schellw. type, a form which is rather widely distributed in America and also occurs in lower horizons as the Cottonwood limestone. I beg to remark that I have at my command a rather large amount of material in North American Fusulinas, most of which comes from the National Museum. *Fusul. cylindrica* does not occur at all in America. I hope to be able to finish my work on the Fusulinas next winter and will then send it to you. I regret that I have not enough separates of my earlier papers in this subject. . . . .

With my kindest regards,

Yours very truly,
(*Signed*) E. SCHELLWIEN

Since the above letter was written H. Yabe, of the Imperial University of Tōkyō, has published "A Contribution to the Genus Fusulina" in which occurs the following statement concerning specimens of *Triticites secalicus* Say sent him by Dr. Girty:

As I examined their sections under the microscope, I was fully convinced of the correctness of his remarks on the peculiar structure of the form; yet I am still in doubt whether it is possible to separate satisfactorily the American form from the group of *Schwagerina* with a fusiform shell, such as *S. fusulinoides* Schellwien and *S. fusiformis* Krotow. The former, according to Schellwien, has "die grosse Centralkammer, die Hin- und Herbiegung der Septen, die in der median Ebene nie den Boden erreichen, Merkmale welche den Fusulinen zukommen," while *Triticites secalicus* possesses, besides these characters, the thick septa of a *Fusulina* s. s. Therefore, until more important differences from *Fusulina* s. s. and *Schwagerina* are found, it seems to me unnecessary to keep *Triticites* as a distinct genus, or even as a new subgenus.[1]

Dr. Schellwien in his last monograph on the Fusulinas under the observations relating to the species *F. montipara* (Ehrbg.) Möller makes the following statement:

[1] *Jour. of the College of Science, Imperial University*, Vol. XXI, Art. 5, 1906, p. 5.

The most important characters of our species consist in the described manner of rolling up, the marked prominence of the mouth, but especially in the slight folding of the septa, a peculiarity which characterizes the majority of American Fusulinas and has led Girty to describe a genus of his own, viz., *Triticites*.[1]

The important point to be noted in all these references to Schellwien's work is that he *always* referred the American forms under discussion to the genus *Fusulina*.

Professors Grabau and Shimer in their excellent work on "North American Index Fossils" list the abundant American species as *Fusulina secalica* (Say) followed by *F. cylindrica* in parentheses as a synonym which is stated to be widely "distributed throughout the Middle and Upper Carbonic."[2] Professor Ernst Koken on his world paleogeographic map of "Land und Meer zur permischen Zeit" shows the genus *Fusulina* in Kansas.[3]

Recently Dr. Beede has found typical Schwagerinas in the Neva limestone associated with *Fusulina* of the *longissima* type on the one hand and with a micro-foraminiferal fauna of Permo-Carboniferous character on the other, similar to that described by Spandel.[4]

It appears, therefore, that the evidence from the Foraminifera is much more strongly in favor of the general correlation which I have made of the Upper Paleozoic rocks of Kansas than I had claimed.

The following statement by Dr. Girty is to be noted: "In a paper just received Mr. Yabe expresses the opinion that the generic term *Triticites*, which I introduced for the type of *Fusulina* found in the Mississippi Valley, is a synonym not of *Fusulina* but of *Schwagerina*."[5] Then follows nearly a page discussion of the correlation of the Kansas deposits, providing this *change* in generic position of the specimens which he had named *Triticites* be accepted. Dr. Girty

[1] *Palaeontographica*, Vol. LV, 1908, p. 186. Dr. Lewis A. Rhoades, professor of Germanic languages and literatures in the Ohio State University, has looked over this translation together with some others in this article and has kindly suggested some changes which I have made.

[2] *Op. cit.*, I, 1906, p. 12.

[3] *N. Jahrbuch f. Min., Geol., u. Pal.*, Festband 1907, p. 546 and Pl. XIX.

[4] See *Univ. Geol. Surv. Kan.*, Vol. IX, 1909, pp. 348, 374, and Dr. Beede's review of "The Guadalupian Fauna" in *Jour. Geol.*, Vol. XVII, 1909, p. 677.

[5] "The Guadalupian Fauna," *op. cit.*, p. 44.

does not say where this paper by Mr. Yabe may be found; but it appears probable that it is the one cited above. If this be correct then the statements by Mr. Yabe touching this question are as follows: "I am still in doubt whether it is possible to separate satisfactorily the American form [*Triticites*] from the group of *Schwagerina* with a fusiform shell. . . . . Therefore, until more important differences from *Fusulina* s. s. and *Schwagerina* are found, it seems to me unnecessary to keep *Triticites* as a distinct genus or even as a new subgenus."[1] In this paper and preceding ones Dr. Beede and myself have used the generic names of *Fusulina* and *Schwagerina* in the sense in which they are generally used by European and American paleontologists who are particularly acquainted with the Paleozoic Foraminifera; not in the sense here suggested by Dr. Girty.

Dr. Girty cites two other genera, *Pseudomonotis* and *Bakewellia*.[2] The genus *Pseudomonotis does* occur in rocks in Kansas considerably older than those which I have considered Permian; but such occurrence had not been reported when my early papers were published. In regard to *Bakewellia* Dr. Girty says: "After critically examining the best specimens of *Bakewellia* which could be obtained I have been brought to entertain serious doubts as to their generic identity with the Bakewellias of the English Permian as represented in King's monograph. The dentition appears to be different and they seem to lack the characteristic series of ligamentary pits." Dr. Beede who has collected and studied a large number of specimens belonging to this type says that "some of the species probably belong to Yakowlew's genus *Cyrtodontarca* from the Permo-Carboniferous of southeastern Russia, while the others may be closely related to them. The Coal Measures rocks of the world, so far as I am aware, nowhere exhibit the faunal assemblage of these shells and the associated pelecypods found in these strata in Kansas."[3]

The conclusions of Professor Fritz Frech as given in his discussion of the line between the Dyas [Permian] and Carboniferous is of decided interest in this connection and corroborative of the views of Dr. Beede. Dr. Frech wrote as follows, as translated by the late Associate Professor Charles W. Mesloh of the Ohio State University:

[1] *Loc. cit.*, p. 5.

[2] "The Guadalupian Fauna," *op. cit.*, p. 43.

[3] *Jour. Geol.*, Vol. XVII, p. 676.

The dividing line between the Carboniferous and Dyas [Permian] formations cannot be drawn with full certainty in every region since, especially in the Dyas, the development of a local flora is nearly always the rule and decisive differences do not exist in the brachiopod fauna.

Yet an agreement seems to be gradually forming everywhere: The line dividing the Carboniferous from the Rothliegende [lower Permian of Germany] is generally placed between the Ottweiler and Cusel beds; only concerning the determination of the age of the French equivalents of both do differences of opinion still exist.

It is everywhere easy to distinguish Schwagerina strata and the Arta [Artinsk] stage where the Medlicottiadæ and the oldest Arcestidæ occur. If the Arta stage and the Sosio limestone is considered a transitional horizon, i. e., as Permo-Carboniferous, there remains almost nothing of our formation.

Also, where the characteristic Dyas bivalves (*Pleurophorus*, *Schizodus*, *Bakewellia*, *Pseudomonotis*) occur in masses (Kansas) there can be no doubt about the dividing line. The great development of the Stegocephala, whose Carboniferous ancestors occur sparingly, is also characteristic of the Dyas.

On the other hand, the development of the still very widely distributed brachiopods is such, that only in the lower Dyas of the Mediterranean district a few new genera, and in the north only a few new species appear. To offset the slow retrogression of the Carboniferous brachiopod group, as we see e. g. in Kansas, there are no additions of any kind.[1]

Professor Frech's deduction from the evidence of the Kansas pelecypods is quite different from that of Dr. Girty and is important to bear in mind in considering the age of these formations. Dr. Frech wrote that: in the brachiopod formations enter layers agreeing petrographically which contain a fauna of small Dyas bivalves (*Bakewellia*, *Pleurophorus*, *Schizodus*). But in the two transition horizons (Neosho and Chase) the Carboniferous brachiopods predominate. The Marion strata are the first to be filled exclusively by upper Dyas bivalves and with variegated gypsum-bearing marls devoid of fossils.[2]

Dr. Girty states that "he [Prosser] finds the Kansas 'Permian' fauna much more distinct from the underlying Pennsylvanian than appears to me warranted, and he correlates it too confidently with the Russian Permian."[3] In regard to the opinion expressed in the first clause of the above sentence those who have followed this discussion have seen that there are other paleontologists who have

[1] *Lethaea geognostica*, "Lethaea paleozoica," 2. Band, 3. Lief., 1901, pp. 490, 491.

[2] *Ibid.*, 2. Lief., 1899, p. 377. [3] *Op. cit.*, p. 42.

studied the fossils of these deposits who find the differences between the Kansan Pennsylvanian and Permian life greater and more marked than I have ever claimed. As to the second opinion I have attempted to consider *all* evidence concerning the age of these formations, whether it agreed with the results of my studies or not, and to give it due weight in forming my opinion regarding the correlation of these deposits.

Concerning the correlation of the Kansas deposits with the Russian Permian it is interesting to note that Murchison—the author of the Permian system—accepted it. He wrote as follows:

> Only of late years have we obtained information of the Permian species of America. It is interesting to find there that the same genera characterize the last of the Palaeozoic systems as in Europe. In Kansas, Texas, and Nebraska, Permian rocks occur containing Productus, Camarophoria, Strophalosia, Streptorhynchus, Chonetes, Spirifer, Edmondia, Gervillia, Monotis, Schizodus, Murchisonia, Orthoceras, Bellerophon, and Fenestella. Not only are the genera the same there as in the eastern hemisphere, but in several cases the species are identical with those found in the Magnesian Limestone and Zechstein. These fossils have been described by Messrs. Meek and Hayden, Swallow and Hawn, Shumard, and very recently by Geinitz.[1]

Since the writer's last reviews of the literature regarding the correlation of the Upper Paleozoic of Kansas and related regions[2] several papers have been published which are of importance in this discussion. In this last review, however, I seem to have overlooked Dr. C. R. Eastman's paper on the "Carboniferous Fishes from the Central Western States" in which he reviewed briefly the correlation of the Upper Paleozoic formations of the Kansas-Nebraskan area and wrote as follows:

> But in the upper terrane, the so-called "Red Beds" or Cimarron series, which exhibit a thickness further southward of from 1,000 to perhaps 2,200 feet, no fossils have been found which are at all closely related to those of the Coal Measures, and writers are pretty generally agreed in correlating this series with the Upper Permian (Neo-Dyas) of Europe.
>
> In the same way there appears to be good reason for believing that the lower part of the Big Blue series (Chase and Neosho strata) correspond to the Artinsk stage, which is the oldest Permian of Russia.[3]

[1] *Siluria*, 5th ed., 1872, pp. 341, 342.

[2] *Jour. Geol.*, Vol. X, 1902, pp. 721–37; *Amer. Geologist*, Vol. XXXVI, 1905, pp. 142–62.

[3] *Bull. Mus. Comp. Zoölogy Harvard College*, Vol. XXXIX, 1903, p. 165.

I will now mention several articles which are somewhat remotely related to the Kansas question. A collection was made in 1901 from the Wichita beds near Seymour, Baylor County, in northern Texas for the Royal Museum of Munich by Charles H. Sternberg who had previously collected in the same general region for the Museum of Comparative Zoölogy of Harvard University and for Professor Cope, a popular account of which may be found in his book.[1] The specimens sent to the Royal Museum of Munich have been described by Dr. Ferdinand Broili and L. Neumayer and it is to be especially noted that Dr. Broili made a trip to this country and spent two weeks in the field with Mr. Sternberg while the collection was being made. Dr. Broili in his monograph describing the Permian Stegocephals and reptiles of Texas in this collection has expressed the following opinion concerning the age of the deposits in Vermilion County, Illinois, which Professor Cope called Permian, and those near Seymour in northern Texas under his general discussion of the Permian of Illinois and Texas: The Wichita beds in Texas compared with the bone bed of Illinois in my opinion represent in point of time the younger formation.[2] Near the close of this discussion Dr. Broili again referred to the correlation of the Permian deposits of these two states as follows: These circumstances, I believe, make the supposition appear legitimate that the strata of Texas, when compared with exposures in Illinois, represent in point of time the younger formation. Another point which likewise favors this opinion is the fact that the genera from the two localities agree, but not the species.[3]

Finally, near the close of the monograph, under his general conclusions, Dr. Broili made the following statement concerning the vertebrate fossils: As we may then infer from the foregoing, the vertebrate fossils from the North American Permian consequently afford a considerable number of points of similarity with European and African forms; these relations might turn out to be even closer, especially if the Russian deposits should be more carefully investigated in their paleontological relations.[4]

[1] *The Life of a Fossil Hunter*, 1909, pp. 205–65.

[2] *Palaeontographica*, Vol. LI, 1904, p. 5. This monograph, however, did not come under my notice until after the publication of my paper of September, 1905.

[3] *Ibid.*, p. 6.

[4] *Ibid.*, p. 105.

Broili's monograph is followed by L. Neumayer's paper on the coprolites of the Texas Permian, which form a part of the above-mentioned collections.[1]

Professor Case has spent considerable time in studying the stratigraphy and fauna of the Red Beds of northern central Texas and has published several papers relating to the subject. One is entitled "The Character of the Wichita and Clear Fork Divisions of the Permian Red Beds of Texas."[2] The last one is called "A Great Permian Delta and Its Vertebrate Life, with Restorations by the Author."[3] A slightly earlier one is "On the Value of the Evidence Furnished by Vertebrate Fossils of the Age of Certain So-called Permian Beds of America."[4] In this paper the vertebrate evidence concerning the age of certain beds in Illinois and Texas is considered and the author's conclusions are as follows:

1. The evidence from vertebrates is not sufficient to demonstrate the Permian age of the beds in Illinois and Texas, they may reach down into the Carboniferous or they may extend upward into the Triassic.

2. There is no unlikelihood that reptilian life began in the Carboniferous. The evidence is rather affirmative than otherwise.

It is becoming more and more evident from the vertebrate paleontology that the Red Beds of North America and their eastern equivalents represent an enormous interval of emergence which may well have begun while Carboniferous (Pennsylvanian) forms still lingered in the waters and have continued until Triassic types were well established.[5]

The last paper dealing with the stratigraphy of this part of Texas was read by Professor C. H. Gordon at the Baltimore meeting and was entitled "The Red Beds of the Wichita-Brazoo Region of North Texas." He stated that—

formations to which the names Wichita and Clear Fork have been given, when traced along their strike toward the southwest, are found to grade into those included under the terms Cisco and Albany. The former have been regarded as Permian, while the latter have usually been assigned to the Pennsylvanian. Some authors, however, have suggested that the Albany should be considered Permo-

[1] *Palaeontographica*, Vol. LI, 1904, pp. 121–28, Pl. XIV.

[2] *Am. Mus. Nat. Hist.*, Vol. XXIII, 1907, p. 659.

[3] *Pop. Sci. Month.*, Dec. 1908, p. 557.

[4] *Jour. Geol.*, Vol. XVI, Sept.-Oct., 1908, p. 572.

[5] *Ibid.*, p. 580.

Carboniferous. . . . . It is the conclusion of the author that the Red Beds of this region are the near-shore representatives of the Albany and the decision as to their age will rest upon that of the latter.

The above paper in part appears to support the earlier conclusions of Professor W. F. Cummins who had "found the fact well established that the Wichita and the Albany divisions were the same in time of deposition."[2] This opinion was positively and clearly stated in 1908 by Professor Cummins in his paper on "The Localities and Horizons of Permian Vertebrate Fossils in Texas" where he wrote as follows:

These beds in the southern part of this field were called the Albany beds and were assigned to the Coal Measures. Subsequent study, however, disclosed the fact that the beds were stratigraphically continuous with the Wichita, being simply deposits in deeper waters, and in all subsequent publications they have been included in the Wichita, referred to the Permian, and the name Albany dropped.[3]

Dr. Percy E. Raymond has discovered reptilian and amphibian fossils near Pitcairn, fifteen miles east of Pittsburgh, Pennsylvania, in the upper part of the Pittsburgh red shale which occurs near the middle of the Conemaugh formation of the Pennsylvanian series.[4] These fossils have been described by Professor Case who states that "in general the collection resembles rather those from Texas than those from Illinois, but the specimens are far too few to base any generalizations as to distribution upon them."[5] His conclusion is that—

it certainly places the advent of a distinctly terrestrial reptilian fauna earlier than has hitherto been supposed. The suggestion may not be impossible that conditions for terrestrial life of a high order were reached earlier in the east than in the west, and that the Carboniferous swamps of Pennsylvanian time, giving place to upland surfaces before the advance of the Appalachian uplift, made possible a type of life that was homotaxially equivalent to a similar type, which developed at a later time in the west.[6]

Dr. I. C. White regards this discovery by Dr. Raymond as strongly confirmatory of the Permo-Carboniferous age of the main portion of

[1] *Science*, N. S., Vol. XXIX, May 7, 1909, p. 752.

[2] *Trans. Texas Acad. Sci.*, Vol. II, 1897, p. 97.

[3] *Jour. Geol.*, Vol. XVI, pp. 738, 739.

[4] *Science*, N. S., Vol. XXVI, Dec. 13, 1907, p. 835.

[5] *Annals Carnegie Mus.*, Vol. IV, 1908, p. 235.

[6] *Ibid.*, p. 240.

the Conemaugh, which he had suggested at an earlier date,[1] and writes as follows concerning it: "The possibility that the lowest *Conemaugh reds* might mark the dividing line between important formations, such as the true *Coal Measures* and the *Permo-Carboniferous*, has received strong confirmation during the past year."[2] In the chapter on the "Monongahela Series" Dr. I. C. White states that "hence there can be little doubt that this upper two-thirds of the *Conemaugh series*, together with the deposits of the *Monongahela*, correlate in time with the *Permo-Carboniferous* beds of Europe."[3]

Mr. Ralph W. Stone has published the following opinion concerning the age of the Dunkard formation, which is the one succeeding the Monongahela:

> The organic remains of the Dunkard group, according to David White, comprise fossil plants in large numbers and ostracods with occasional occurrences of pelecypods and fish fragments. . . . .
>
> This flora of the Dunkard is interesting on account of species that are either unique or closely related to forms present in rocks of Mesozoic age.[4]

Dr. G. C. Martin has recently made the following statement concerning the same question: "The equivalents of these beds [Dunkard] in Pennsylvania and West Virginia have, from a study of their floras and faunas, been referred to the Permian series of the Carboniferous. Some doubt still exists as to their age, but in all probability they are, in part at least, Permian."[5]

In the "Tableau du Synchronisme des Assises Permiennes" in the last edition of De Lapparent's *Traité de géologie* the Permian is subdivided into three *étages* which in ascending order are the Artinskian or Autunien, Penjabien or Saxonien, and Thuringien. The Kansan formations are correlated as follows in this table: the Neosho and Chase are put in the Artinskian or Lower Permian; the Marion and Wellington in the Penjabien or Middle Permian; and the Red Beds or Cimarron series in the Thuringien or Upper Permian.[6] Under the discussion of the Penjabien or Middle Permian

[1] *W. Va. Geol. Surv.*, Vol. II, 1903, p. 256.

[2] *Ibid.*, Vol. Two (A), 1908, p. 622.

[3] *Ibid.*, p. 687.

[4] *Geologic Atlas U. S.*, Folio No. 121, 1905, p. 7.

[5] *Ibid.*, Folio No. 160, 1908, p. 8.

[6] *Op. cit.*, 5th ed., 1906, p. 1026.

is the statement that "Les *Marion beds* du Kansas, à *Bakewellia* et *Pseudomontis*, sont peut-être de cet âge, ainsi que les *schistes de* Wellington."[1] Under that of the Thuringien it is stated that "Les couches de *Cimarron*, qui font partie des *red beds* et surmontent l'assise de Wellington, renferment dans l'Oklahoma des lits à *Pleurophorus* et *Bakewellia*. Il s'y trouve du gypse et des dolomies."[2]

On the "Carte Géologique de l'Amérique du Nord," compiled by Bailey Willis and published in 1906 for distribution at the tenth session of the International Geological Congress in September of that year in Mexico, the area of the rocks under discussion extending from southeastern Nebraska southwesterly across Kansas and Oklahoma to central Texas is mapped as Permian. Professor Willis made the following statement concerning it:

> Les couches de la période Carbonifère sont parmi les plus differentiées de l'Amérique du Nord; on y reconnaît ordinairement trois divisions principales: le Mississippien, le Pennsylvanien et le Permien, et ces divisions sont représentées sur la carte autant qu'elles peuvent être distinguées. . . . . Le Permien (Formation Dunkard) de la Pennsylvanie n'est pas représenté séparément. Le Permien du Nouveau Brunswick est montré sur la carte ainsi que la large zone de grès permiens et de couches rouges qui s'étend vers le sud-ouest, depuis le Kansas jusqu'au Texas.[3]

Professors Chamberlin and Salisbury fully accept the Permian age of the Kansas deposits as is shown by the following excerpts from their magnificent work on general geology:

> West of the Mississippi, the Permian system has a more extensive development [than to the east], though far less widespread than the Pennsylvanian. The Permian strata are best known in Texas, Kansas, and Nebraska, and though the sea was not entirely excluded from this region, it appears, where present, to have been shallow. Locally and temporarily, inland seas were cut off from the ocean. Early in the period the Texan area of sedimentation seems to have been separated from the Kansan by the beginnings of the Ouachita mountains. . . . .
>
> In Kansas and Nebraska the older Permian beds are marine. . . . . The marine Permian of Kansas is overlain by beds containing gypsum and salt and possessing other features which show that the open sea of the region was succeeded by dissevered remnants, or by salt lakes whose supply of fresh water was exceeded

[1] *Ibid.*, p. 1016.

[2] *Ibid.*, p. 1025.

[3] *Congrès Géologique International*, Compte Rendu, X^ème^ Session, Mexico, 1906, 1st fas., 1907, p. 219.

by surface evaporation. Connected with these saline and gypsiferous deposits, and overlying them, are the "Red Beds," sometimes referred to the succeeding Trias; but they appear to be late Permian, in the main at least.[1]

Professor Scott also states a similar conclusion in his general work on geology where he says that:

In the region beyond the Mississippi the Permian beds thicken southward, attaining in southern Kansas a thickness of 2,000 feet, and in Texas of more than 5,000 feet. The mountains of Oklahoma, which may have been raised late in the Carboniferous or early in the Permian, separate the Texas and Kansas areas. . . . .

In the latter part of the period, lagoons were cut off from the sea and converted into salt and bitter lakes in which the salt and gypsum of Kansas and the gypsum of Oklahoma and Texas were precipitated. Occasionally the sea broke into these lakes, bringing a marine fauna with it for a short time.[2]

Professor Scott is an accomplished vertebrate paleontologist and under his account of "Permian Life" is the statement that—

the most important character that distinguishes the life of the Permian from that of all preceding periods is the appearance in large numbers of true *Reptiles*. There is no reason to suppose that such a variegated reptilian fauna can have come into existence suddenly, and their ancestors will doubtless be discovered in the Carboniferous; but while no true reptiles are certainly known from the latter, in the Permian they are the most conspicuous elements of vertebrate life.[3]

Under the description of the Carboniferous Dr. Kayser, the distinguished professor of geology in the University of Marburg, writes that: The marine Upper Carboniferous of Kansas has become known to us in particular through the numerous works of Charles Prosser. Tschernyschew and others have brought out most prominently the great similarity of the fauna with that of the Timans and Urals.[4]

Finally, under the description of the Permian Dr. Kayser states:

In the United States we find in the east (Virginia, Pennsylvania, and so forth) conformably over the productive upper Carboniferous [Upper Productive Coal Measures] the so-called Barren Measures [Upper Barren]. They contain *Callip-*

[1] *Geology*, Vol. II, 1906, pp. 620, 621; also, see *A College Text-Book of Geology*, by the same authors, 1909, pp. 660, 661.

[2] *An Introduction to Geology*, 2d ed., 1908, p. 639.

[3] *Ibid.*, p. 652.

[4] *Lehrbuch d. Geologie*, 3d ed., Pt. II, "Geologische Formationskunde," 1908, p. 236.

teris conferta, *Taeniopteris*, and other characteristic Permian forms together with Carboniferous types of plants exposing, probably, a representation of our Rothliegende.

In the western and southern states, on the other hand, there occurs quite similar to that in Russia, closely associated with extensive marine upper Carboniferous deposits, in large part chalky, equally extensive marine Permian deposits, likewise largely chalky. This is especially so in Kansas, Nebraska, and the adjoining territory. The beds in question, designated by very different names (Wichita and Clear Fork beds [Cummins], Neosho, Chase and Marion [Prosser], etc.), contain in the lower part numerous Theriodonts (*Naosaurus* and others), Stegocephals (*Eryops*, *Cricotus*), and fish (*Pleuracanthus*, *Janassa*, etc.), recognized by Cope as Permian; in the upper part, beside numerous mostly Carboniferous species (especially Brachiopods—*Productus*, *Marginifera*, *Enteles*, *Derbyia*, *Camarophoria*, *Spirifer*, etc.—, Lamellibranchs and Gastropods), are Permian Ammonites (*Medlicottia*, *Popanoceras*, *Waagenoceras*). Above follows, as representative of the upper Permian, a predominant red-colored, unfossiliferous formation composed of sandstones, clays, and shales, gypsum and salt bearing, comparable to the Russian Tartarian group.[1]

The Tartarian is the upper stage of the Russian Permian and some of the Russian geologists have considered it as of Triassic age.

Dr. E. H. Sellards has described under the title of "Types of Permian Insects"[2] a rich insect fauna found in the Wellington shales, three and one-half miles southeast of Banner City, Dickinson County, Kansas. Over two thousand specimens have been collected and it is stated to be "the most complete record of Permian insect life thus far obtained."[3] The last paper contains a section on the "Correlation of the Insect-bearing Horizon" in which the most striking characters of the fauna are pointed out. It is stated:

The order Plecoptera, or Ephemerids, is somewhat abundant in the Wellington shales. In Part II of this paper I have described ten genera and thirteen species constituting a new family of this order. Insects which appear to be prototypes of the Ephemerids exist in some abundance in the Coal Measures. Handlirsch has recognized Ephemerids as occurring sparingly in the Permian of Russia. With this exception true Ephemerids have not previously been identified from Paleozoic deposits. The relative abundance of this group of insects in the Wellington shales affords an exceptionally strong argument for the Permian age of that formation.[4] . . . .

[1] *Ibid.*, pp. 301, 302.

[2] *Am. Jour. Sci.*, 4th ser., Vol. XXII, 1906, p. 249; *ibid.*, Vol. XXIII, 1907, p. 345; and *ibid.*, Vol. XXVII, 1909, p. 151.

[3] *Ibid*, 4th ser., Vol. XXII, p. 249.

[4] *Ibid.*, Vol. XXVII, Feb., 1909, p. 170.

It has usually been observed in collecting from Paleozoic localities, that cockroaches exceed in number of individuals all other insects combined. In the Wellington shales the cockroaches are much in the minority. A collection of something over two thousand insect specimens was found to contain only about seventy cockroaches. From these, two genera and ten species were identified. Of the two genera, one is the well-known Coal Measure and Permian genus *Etoblattina*. The second genus is new. The ten species obtained are new. The rarity of cockroaches in the Wellington is in marked contrast to their relative abundance in most Coal Measure and early Permian localities.[1] . . . .

Among the few insects obtained from the Permian formation of Russia, Handlirsch recognizes, as previously stated, the occurrence of true Ephemerids. The Russian deposits have also yielded forms regarded as representing Paleohemiptera and Mantoidæ. These last two groups have not been recognized in the Kansas Permian. The presence of the Ephemerids, however, forms a strong tie in common between the insects of the Russian and the Kansas Permian.[2]

Fossil plants which are associated with the insects at this locality have also been described by Dr. Sellards, and he writes in no uncertain way concerning their geological age. He says:

In the writer's opinion, the plant fossils indicate unequivocally the Permian age of the formation from which they come. The evidence as to the age of the Wellington shales, derived from the flora, is thus summarized in the report referred to [*Kansas University Geological Survey*]: "More than two-thirds of the Wellington species are either identical with or most closely related to species or genera characteristic of the European Permian. The points which seem to have the most importance as bearing on correlation of the Wellington are the following: (1) The complete absence from the Wellington of species in any way confined to or distinctive of the Coal Measures. (2) The comparatively small number of species originating as early as Upper Coal Measure time. (3) The presence of a few species common to and characteristic of the Permian of Europe. (4) The close relation of the new forms to species characteristic of the European Permian. (5) The distinctly Permian facies of the flora as a whole and its marked advance over the flora of the Upper Coal Measures.

"The advance in the flora consists in the number of species and in the abundance of individuals of callipterid and tæniopterid ferns, and of the new fern genus, *Glenopteris*, which appears to be related, on the one hand, to callipterid ferns of Permian types, and, on the other, to the Triassic genera *Cycadopteris* and *Lomatopteris*.

"The evidence derived from the fossil plants as a whole seems to assure the reference of the Wellington to the true Permian in the European sense."

[1] *Am. Jour. Sci.*, 4th ser., Vol. XXVII, Feb., 1909, p. 171.

[2] *Ibid.*, pp. 172, 173.

This conclusion drawn from the plant fossils is now fully confirmed by the evidence derived from the insects.[1]

Dr. Sellards also describes a flora from the Wreford limestone concerning which he writes as follows:

A good deal of interest is attached to the discovery of plants in the Wreford limestone, especially as this formation has been recently regarded as the base of the Permian in Kansas. Nine species have been obtained from this locality as follows: *Baiera* sp., *Callipteris conferta*, *Callipteris* sp., *Cardiocarpon* sp., *Carpolithes* sp., *Cordaites* sp., *Rhabdocarpus* sp., *Sigillaria* sp., *Walchia piniformis*. The collection obtained from this formation is small and comes from a single locality near Reece, Kan. The association of the flora so far as obtained is with Wellington rather than with Coal Measures flora. The presence of *Walchia* in abundance, and of callipterid ferns, along with the small species of seeds common to the Wellington, together with the absence, so far as yet noted, of all of the common Coal Measures species, gives the flora of the Wreford, as developed at Reece, a distinctive Permian facies.

Coal Measures species, although rare in the collection obtained from the Wreford limestone at the Reece locality, recur in some abundance in the horizon at Washington, regarded by Beede as near the top of the Chase formation.[2]

At the Baltimore meeting, December 31, 1908, Dr. Beede presented a most important paper on the "Relationships of the Pennsylvanian and Permian Faunas of Kansas and Their Correlation with Similar Faunas of the Urals." He stated that "owing to physical changes which occurred during the close of Pennsylvanian time, there occurred a great reduction of Pennsylvanian species, followed by the introduction of Permian species. This introduction of new species becomes very noticeable in the Elmdale formation and its base is considered the base of the Kansas Permian."[3]

Since the above was written the writer has received the May-June number of the *Journal of Geology* in which appears the correlation paper on the "Upper Carboniferous" by George H. Girty[4] followed by the one on "The Upper Paleozoic Floras, Their Succession and Range," by David White,[5] both of which were read at the Baltimore

[1] *Op. cit.*, p. 173. Also see *Univ. Geol. Surv. Kansas*, Vol. IX, 1908 [1909], p. 463.

[2] *Ibid.*, Vol. IX, pp. 463, 464.

[3] *Science*, N. S., Vol. XXIX, April 16, 1909, p. 637. Also see *ibid.*, May 7, 1909, p. 752.

[4] *Op. cit.*, Vol. XVII, July, 1909, pp. 305–20. [5] *Ibid.*, pp. 320–42.

meeting of the American Association for the Advancement of Science, in December, 1908. It is too late to discuss or make use of these papers in this article. It may be said, however, that Dr. Girty states that "the propriety of employing the term Permian in the geology of North America seems to me decidedly doubtful, at least in so far as the evidence of invertebrate fossils is concerned."[1] Mr. White, on the other hand, discusses, under "the Permian floras," following the account of "the Carboniferous floras," those from the Permian of Prince Edward Island, the Dunkard of southwestern Pennsylvania and West Virginia, the Chase of Kansas, and the Wichita of Texas, all of which he apparently places in the Permian. These will be followed immediately by another correlation paper on "The Faunal Relations of the Early Vertebrates" by Professor Samuel W. Williston.[2] Later will appear a critical review of "The Guadalupian Fauna,"[3] and a correlation article on "The Bearing of the Stratigraphic History and Invertebrate Fossils on the Age of the Anthracolithic Rocks of Kansas and Oklahoma,"[4] both of which are by Dr. J. W. Beede. Finally, it may be said that Dr. Beede has studied the stratigraphy, distribution, and invertebrate paleontology of the Upper Paleozoic or Anthracolithic deposits from Nebraska to Texas more thoroughly than any other geologist has yet done and, therefore, his conclusions are entitled to most careful consideration.

JULY 24, 1909

While this article is passing through the press certain additional information has reached me. The following letter from Professor Yakowlew is important since it gives a summary of the present opinion of the Russian geologists concerning the classification of the Artinsk:

INSTITUTE OF MINES, ST. PETERSBURG
November 30, 1909

Professor Ch. S. Prosser, Ohio State University, Columbus, Ohio:

DEAR SIR: You ask me some questions concerning the Upper Paleozoic deposits of Russia. You wish to know where I draw the line between the Carboniferous and Permian systems in Russia and in which system I place the Artinsk.

[1] *Jour. Geol.*, Vol. XVII, July, 1909, p. 319.

[2] *Ibid.*, pp. 389–402.

[3] *Ibid.*, pp. 672–79.

[4] *Ibid.*, pp. 710–29.

The question about the Artinsk can be solved by comparing its fauna with the fauna of the Permian lying higher and that of the upper Carboniferous lying lower. I think there would be more resemblance with the fauna of the upper Carboniferous. However, the thickness of the Artinsk and the Permian is not very great and their fauna may not be very different. On the other hand some Russian authors are inclined to relate Artinsk to the Permian system; they do so on historical foundation, as the extent of the Carboniferous system had been determined in science before Murchison and we have no right to enlarge it by adding Artinsk. We may sooner unite Artinsk with the Permian system, the extent of which is not so definitely established as that of the Carboniferous. In Russia the term Permocarboniferous is used to designate Artinsk, if it is not related to the Permian nor to the Carboniferous systems, but placed between them, as done by Karpinsky (though without sufficient paleontological grounds), when he established Artinsk. If Artinsk is united with Carboniferous system, the term Permocarboniferous will not have to be used in the sense just mentioned, it will be superfluous. No one in Russia is inclined to designate by the name Permocarboniferous the total of the Permian and the Carboniferous systems, as it is sometimes done in the West of Europe. The Russians keep to one of the two opinions, they either take Artinsk for the Permocarboniferous, that is for the intermediate between the Carboniferous and the Permian, or unite it with the Permian. But I do not think anyone would unite it with the Carboniferous. I think that there might be Artinsk in Kansas and in Nebraska, as there is much in common between the Donetz fauna described by me, with the fauna of Kansas and Nebraska. But whether the Permian fauna exists in North America is an open question to me. . . . .

Yours sincerely,

NICHOLAS YAKOWLEW

Dr. Fritz Frech, the distinguished professor of geology in the University of Breslau, has written me as follows under date of December 21, 1909:

Answering your kind letter of the end of October I give my opinion on the Dyas [Permian] as follows: I include the Arta [Artinsk] stage in the lower Dyas as the type of this lower stage. I have had no ground to change the opinions, expressed in *Lethaea palaeozoica* (2. Band, commencing on p. 493), concerning the correlation of the Dyas.

A letter from Alexander Krasnopolsky, Géologue en chef du Comité géologique de Russie, was received January 6, 1910, a translation of which follows:

The Permo-Carboniferous deposits of the western slope of the Urals—investigated by me—represent two formations, the Artinsk and the Kungur.

These deposits are characterized (aside from the species particularly peculiar to them) by Carboniferous and also by Permian species.

Since these deposits lie directly over the Fusulina limestone of the Urals (which must be looked on as equivalent to the very uppermost formations of the Carboniferous), we may not refer the deposits in question to the Carboniferous system.

On the other hand, I do not find it wholly easy to refer these deposits (and the Lower and Middle Productus limestone of India corresponding to them) to the Permian formation, as I earlier thought possible; for the Permian system, in the sense used by Murchison, itself must begin only with the formations which lie over the Kungur strata—more exactly, only with the limestones of the Province of Kostroma, which contain an older fauna than does the Zechstein of western Europe.

It is interesting to note that what Dr. Tschernyschew said of the outcrops of Artinsk and Upper Carboniferous near the city of Oufa in eastern Russia is certainly paleontologically suggestive of the Kansan deposits. He wrote as follows:

Les bords pittoresques du lac de l'usine de Simsk offrent une coupe classique pour l'étude des dépôts d'Artinsk et des sédiments carbonifères sousjacents. . . . .

Les calcaires qui alternent avec les grès consistent par places presque en entier en grosses fusulines (*Fusulina Verneuili* Moell.). Près de la même digue on voit apparaître de dessous les grès d'Artinsk et en concordance avec lui le grès carbonifère qui contient, avec coquilles de *Fusulina Verneuili* Moell., *Productus semireticulatus* Mart., *Productus longispinus* Sow., *Martinia glabra* Mart., des restes de *Dielasma* et de *Spirifer* (du type de *Spirifer mosquensis* Fisch.).[1]

The argument has been advanced that because Carboniferous brachiopods occur in the Kansas deposits, which I have referred to the Permian, they could not belong in the Permian system. Professor Diener has studied exhaustively the faunas of the Salt Range Productus limestone of India and the Alpine Permian and in a recent letter he refers to the results of this study. If his conclusions are correct it will be seen that the occurrence of Carboniferous brachiopods in deposits superjacent to those which contain Foraminifera characteristic of the uppermost Carboniferous of Russia, as is the case in Kansas, is no argument at all against the Permian age of these Kansan deposits. Professor Diener calls attention to the dis-

[1] *Guide des Excursions du VII Congrès Géologique International*, III (A partir de la ville d'Oufa jusqu'au versant oriental de l'Oural), 1897, pp. 21, 23.

pute as to the Carboniferous or Permian age of the Salt Range Productus limestone and then says:

> This erroneous correlation [with the Upper Carboniferous] is based on the exaggerated importance of numerous species of Brachiopoda which are common to both rock-groups [Carboniferous and Permian]. . . . . I have examined large collections of Himalayan anthracolithic fossils, the descriptions of which have not yet been published, and I am convinced now of the absolute impossibility of basing any safe correlation on the evidence of brachiopods. I have found that the majority of brachiopods considered hitherto as typical leading fossils of Permian beds are distributed equally through Carboniferous and Permian rocks. Foraminifera are far more important as stratigraphical evidence. The fusulinae of the Productus limestone of the Punjab differ specifically from those of the Russian Upper-Carboniferous rocks. So do the Ammonites, whereas the brachiopod fauna undergoes but very little change between the two systems.
>
> I have recently prepared a paper on the brachiopod fauna of the Alpine Bellerophonkalk. This is a stage, which from its stratigraphical position must be placed rather high in the Permian system. In its brachiopod fauna truly Carboniferous types, however, still predominate, thus proving the insufficiency of brachiopods for exact correlations.[1]

Mr. G. B. Richardson, Dr. J. W. Beede, and Mr. David White presented papers, based on their field work of last summer, at the Boston-Cambridge meeting of the Geological Society of America which prove the Permian age of the Kansas deposits which I have referred to that system. The following abstract of Dr. Beede's article on "The Correlation of the Guadalupian and Kansas Sections" was published in the "Preliminary List of Papers" for that meeting:

> The Guadalupian limestones of western Texas and southern New Mexico are overlain by the Pecos Valley Redbeds. These beds present the same lithologic features and are of similar succession as the Redbeds on the eastern side of the Llano Estacado and carry a fauna closely related to them. The gypsums appear to be the equivalents of the Greer gypsums as exposed in Oklahoma and Texas. If this correlation is correct, then the base of the Capitan limestone is on the same stratigraphic level, approximately, as the base of the Elmdale formation of Kansas and the base of the Guadalupian series on the level of the base of the Cherokee shales. The five thousand feet of Hueco beds would fall below this level.

The same list also contained the following abstract of Mr. White's paper on "Permian Floras in the Western 'Red Beds'":

[1] Letter of November 24, 1909.

Characteristic floras, found in a brief tentative search of red beds at three points in Colorado and New Mexico, not only prove Permian age but also indicate great thickness of Dyas in certain "Red Beds" sections in the Rocky Mountains. Examination of lower middle Wichita in Texas and additional collections from Chase (Wreford and Winfield beds) and Wellington of Kansas and from Red Beds within the same limits in Oklahoma confirm lower Permian correlations.[1]

A recent article by Dr. Austin F. Rogers of Stanford University is important in noting the similar mineral deposits in the upper part of the Big Blue series (Lower Permian) of Kansas and those of the Zechstein (Upper Permian) of Germany, and calling attention to the probable arid climate in the northern hemisphere during Permian time which these mineral deposits indicate also prevailed during that time in Kansas. Dr. Rogers writes as follows:

The salt and anhydrite occur in the lower Permian. According to Plate V of the report on Kansas salt,[2] the salt-beds are between the Wellington and Marion formations. Not a single fossil was found on the saltmine dumps, and this is not strange when we consider the conditions under which these deposits were formed. From evidence gathered in various places it seems certain that throughout the northern hemisphere an arid climate prevailed in the Permian. The poverty of fossils, the occurrence of Red-beds, and the presence of extensive beds of gypsum and salt, all point to the fact that Kansas was like the rest of the northern hemisphere during Permian time. Now the occurrence of anhydrite with the salt is additional evidence that the Kansas Permian is like the Permian (Zechstein) of Germany during which time the salt deposits of Stassfurt, Leopoldshall, Vienenburg, and Bernburg were formed. At all these localities anhydrite occurs with salt.[3]

The following recent letter from Professor P. Krotow of the University of Kasan, Russia, who has thoroughly studied the Artinsk and associated formations of Russia, is especially important in giving a brief general account of these formations together with a table showing their correlation with the corresponding ones of western Europe. The letter was written in English in which only two or three minor changes have been made:

The term Permo-Carbon is used in Europe with two meanings: (1) The French call the Permo-Carboniferous system the united deposits of both systems:

[1] Twenty-second winter meeting, Boston-Cambridge, Mass., December 28–30, 1909, p. 24.

[2] *Annual Bulletin of the Mineral Resources for 1908.*

[3] *Am. Jour. Sci.*, 4th ser., Vol. XXIX, March, 1910, p. 260.

the Carboniferous and the Permian; (2) In Russia we call Permo-Carbon the intermediary horizons between the Carboniferous and the Permian systems, characterized by a mixed fauna and flora, consisting of Carboniferous and Permian species with the incorporation of some original species, which are met with only in these layers.

In Russia,[1] as well as in western Europe, these intermediary horizons are composed of layers previously looked upon partly as Carboniferous, partly as Permian.

For instance, in Russia in the composition of Permo-Carbon enter: The Artinsk or pepper sandstone, which Murchison referred to the Carboniferous system, as well as the limestone and plaster-stone of Kungur, which Murchison referred to the Permian. Artinsk or pepper sandstone with Permo-Carboniferous fauna composes the Artinsk-Stufe, the lower layers of Permo-Carbon. It lies immediately on several kinds of limestone (Fusulina limestone and Schwagerina limestone), which must be unconditionally related to the Carboniferous system. On "Artinsk-Stufe" lies the "Kungur-Stufe" which forms the upper layers of Russian Permo-Carbon. On these strata in Russia lie lime-marly Platten which form the transition from the Permo-Carbon to the Permian system. The Permian system itself in Russia begins with coppery limestone and red-clays, on which directly follows the Zechstein-limestone. In Germany in the composition of Permo-Carbon equivalent to Artinsk and Kungur-Stufen, enter: Lebacher Schichten (in Saarbrücken), Brandschiefer (in Saxony), Kohlenrothliegendes (Bohemia).

To make it clearer I give the following scheme:

	European Russia	Western Europe
Permian system	Zechstein Red-clay Coppery sandstone	Zechstein Rothliegendes, etc.
Permo-Carbon	Kungur-Stufe Artinsk-Stufe	Lebacher Schichten Brandschiefer Cuseler Schichten Kohlenrothliegendes, etc.
Carboniferous-Stufe	Fusulina and Schwagerina limestone, etc.	Productive Gruppe Kohlenkalk

As to the question whether Permian-Carbon belongs to the Carboniferous or the Permian system, that, from my point of view, is quite a matter of indifference But we generally connect Permo-Carbon with the Permian system.[2]

July 24, 1909

[1] Krotow, *Artinskische Etage; Geol. Forschungen am West-Abhange d. Urals; Notiz auf d. Brief Herrn Nikitin über Permocarbon.*

[2] Letter of February 19, 1910.

THE FORM OF NANTASKET BEACH

DOUGLAS WILSON JOHNSON AND WILLIAM GARDNER REED, JR.

INTRODUCTION

This paper presents the results of a study of the form of Nantasket Beach, and includes a discussion of the stages of development through which the beach has passed to reach its present form, and of the processes by which that development has been accomplished. Our attention was directed to the Nantasket problem by Professor W. M.

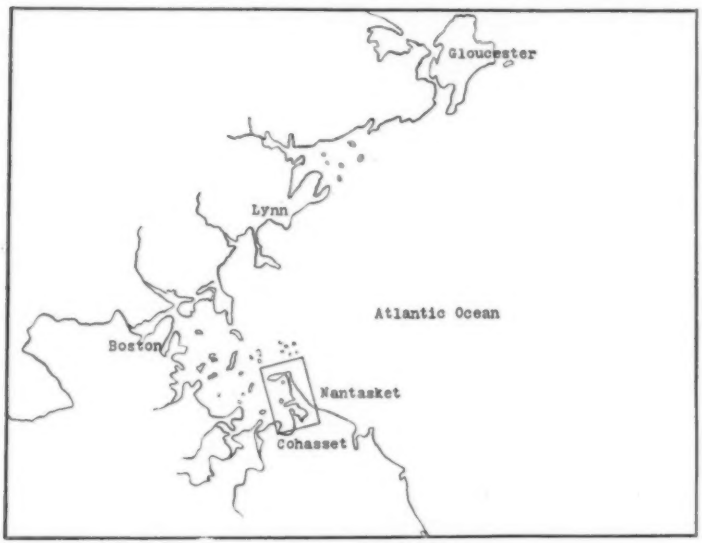

FIG. 1.—Location of Nantasket area.

Davis, who was the first to discover the significance of the abandoned marine cliffs and beaches, and their relation to islands which have long since disappeared. Acknowledgments are also due the Boston street commissioners for assistance in securing old maps for examination; to Mr. E. G. Knight of Hull for information regarding conditions prior to the building of the County Road on Nantasket

Beach; and to Mr. F. M. Hersey of Boston, and the officials of the United States Coast and Geodetic Survey for numerous courtesies. In addition to these gentlemen, our thanks are due to many others in Boston and Hull for various services.

Nantasket Beach lies at the southeastern border of Boston Harbor, separating that portion of the harbor from the Atlantic Ocean (Fig. 1). The name "Nantasket Beach" is generally applied to all of that irregularly shaped lowland between the rocky hill of the Atlantic on the south, and the drumlin known as Allerton Great Hill on the north, and is not restricted to that portion of the lowland immediately bordering the ocean at the present time. As thus defined Nantasket Beach has a width of from a few hundred feet to more than half a mile, and a length of a little more than three miles. In our discussion we include the neighboring district of Hull, as well as several outlying islands, which are more or less closely related to certain phases of our investigation.

THE PROBLEM STATED

A casual study of the Nantasket district makes clear the fact that Nantasket Beach consists of sand, gravel, and cobbles, deposited by wave action between several drumlins which formerly existed as islands. The problem which we have to consider may therefore be described as a problem in island-tying by means of beaches. The tying of islands to each other and to the mainland, by the formation of connecting beaches, has been recognized as a common phenomenon along a youthful shoreline of depression, where islands are apt to be more or less numerous. Boston Harbor occurs on a shoreline of depression, but the islands which help to form the harbor, and which are frequently connected with each other and with the mainland by beaches, do not as a rule represent the summits of hills left as islands by the depression of a maturely dissected mainland. They are for the most part typical drumlins, the trend of whose long axes indicates that the ice-sheet which fashioned them moved from the land southeastward out to sea. It is evident that drumlin islands might be formed along a shoreline of elevation; hence the phenomena about to be described might occur along both of the standard types of shorelines. The principles involved in our discussion remain the same, whether the islands be composed of solid rock or unconsolidated

glacial till; but it will appear that the stages of shoreline development are passed through more quickly, the wave-cut cliffs are more symmetrical, and the past conditions more easily reconstructed where drumlin islands are involved, as in the Nantasket case.

In the following pages we shall briefly review the principles of shoreline development, and then describe in some detail the present form of Nantasket Beach. On the basis of this description, and in view of the principles of shoreline development, we shall endeavor to reconstruct the initial form of the Nantasket district. Still guided by the principles of shoreline development, we shall next trace the successive steps in the development of Nantasket Beach from the initial form to the present form, with brief attention to the changes which will probably occur in the future. It will appear that Nantasket Beach is a very complicated example of island-tying, which illustrates in a remarkable manner the fact that shorelines are the product of systematic evolution according to definite physiographic laws.

LITERATURE

So far as we are aware, no detailed account of the physiography of Nantasket has been published. Professor W. O. Crosby (1893) has described the hard rock geology of the district just south of the beach in great detail and has considered the beach and drumlins at some length. He has also discussed the evidence of post-glacial changes of level in the Nantasket area. Other references to the district here described are found throughout the literature on the Boston Basin, but are not of importance in the present discussion.

In 1896 Professor W. M. Davis published a paper entitled "The Outline of Cape Cod," in which he discussed at some length the principles of wave and current action, and applied these principles in a study of the present form of Cape Cod and the past changes in the outline of the cape. The principles set forth in Professor Davis' essay are considered more fully on a later page.

Dr. F. P. Gulliver in a paper on "Shoreline Topography" (1899) has discussed at length various shore forms, including beaches which connect islands with the mainland or with each other. To such beaches he has applied the name "tombolo." Several types of

tombolos are described, and Nantasket Beach, which might be described as a complex tombolo, is briefly mentioned.

In common with all students of shoreline topography, we are indebted to Dr. G. K. Gilbert's classic studies of lake shores for the elucidation of many of the principles upon which all shoreline studies must be based.

A brief note on "The Geology of the Nantasket Area," containing an outline of the physiography of the district, was published by Professor D. W. Johnson in *Science* three years ago.

THE PRINCIPLES OF SHORELINE DEVELOPMENT

Physiographers recognize two distinct classes of shorelines—those formed by a (relative) elevation of the land, called shorelines of elevation; and those formed by a (relative) depression of the land, called shorelines of depression. It is not necessary to repeat the characteristic features of these two classes of shorelines, nor to trace the successive stages by which young shorelines of each class acquire, by the time they reach maturity, curves of a relatively simple pattern, marine cliffs more or less bold, and shelving beaches at the foot of the cliffs. Initial characteristics and stages of development are both set forth in our best textbooks on physiography.

We may note, however, that the processes of shoreline development involve both wave and current action. It has been shown that wave action is largely confined to the erosion of the land margins, to the transportation of the eroded material a short distance from the shoreline, and to the deposition of the material in the deeper water; and to the heaping-up of sand, gravel, and cobbles into long ridges or beaches, where the conditions favor wave building more than wave erosion. Current action, on the other hand, effects but little erosion, and is mainly effective in the 'longshore transportation of material previously eroded by the waves or brought in by rivers. It has been shown that the combined effects of these two processes is to produce, in time, a shoreline characterized by long, simple curves, and free from sharp angles or other irregularities. Headlands are cut back, or retrograded, and re-entrants are built forward, or prograded, in the attempt made by waves and currents to straighten out the initial irregularities of the shores, and thus to establish a

graded shoreline. The process is analogous to the formation of graded stream profiles by the degrading of elevations and the aggrading of depressions. If the waves cut back faster on one side of a headland than they do at the headland or beyond, and a strong current sweeps along the shore, the formation of a sharp angle at the headland is prevented by the prograding of the shore beyond the headland as rapidly as it is retrograded in the region of pronounced cutting. Thus, in the case of Cape Cod, Professor Davis has shown that the retrograding of the shore in the vicinity of Highland Light, due to active wave erosion, has been accompanied by a prograding of the shore farther north, where successive beaches have been built forward to maintain the simple curvature of a maturely graded shoreline. Equilibrium is reached, or the beach is maturely graded, when a gently curved or straight shoreline is developed; thereafter the headlands and beaches both retrograde gradually under the continued attack of the waves.

Inasmuch as the Nantasket problem involves a complex example of island-tying, we may here consider certain principles underlying the formation of connecting beaches, or tying bars as they are often called. If an island faces a large expanse of open water on which large waves are produced, and these waves come in general from one direction, the end of the island exposed to the brunt of the wave attack will be eroded, and the eroded material will be gradually drifted back along the sides of the island and strung out behind as a spit. In course of time the spit may reach the mainland or another island, and the island-tying is complete. Variations in local conditions may result in various forms of the tying bar; examples of several forms are described by Dr. Gulliver. It is possible that in some cases the bar may be built from the mainland out to the island (Gulliver, p. 192).

Backward tying is not the only form of island-tying to be observed along the shores. Lateral tying is certainly strongly developed in the Boston region, and we believe that many cases now regarded as examples of simple backward tying will prove to be more or less complicated examples of lateral tying. If wave erosion is most active on the eastern end of an island which lies at the mouth of a bay, and which is between two headlands situated to the north and south of

the island (Fig. 2), several types of tying may result under different conditions. If there is no pronounced current action except the on-shore and off-shore tidal currents and the movements of the water due to waves coming from the east, simple backward tying may result (*a*). Under the same conditions as those just outlined, provided that the shallowing of the water inland is favorable, the material eroded from the head of the island may be drifted backward but at the same time northward and southward in curving lines along a zone where the water is of such depth as to favor deposition before reaching the bay head. Similar deposits from the headlands would meet those from the island, and lateral tying by curved bars would result (*b*). These bars might then be prograded, as explained on a previous page, until they formed a nearly straight shoreline between the island and the headlands. If the tidal action were fairly strong, the bars from the island and headlands might not join, leaving each portion as a spit, possibly more or less irregular in form, at its free end (*c*). If a pronounced 'longshore current existed, the waves still coming from the east, the material eroded from the island by wave action might be transported by the current from the island toward the headland, building a bar which would eventually tie the island to the mainland (*d*). In a similar manner a bar built northward from the southern headland might effect the tying of the island to the mainland (*e*). A sufficiently strong tide might prevent the tying in either case by maintaining a tidal inlet. But if the tying were effected,

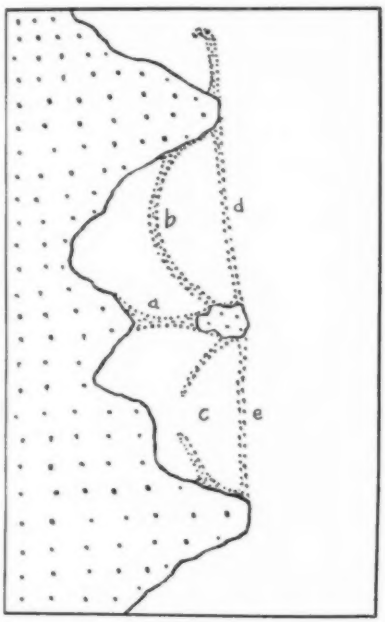

FIG. 2

it should be regarded as lateral tying, the connecting bar being built at right angles to the direction of wave attack, and parallel to the shoreline. Lateral tying similar to that represented by *d* and *e*, Fig. 2, might be produced if the character of the sea bottom caused the waves to break along the line *de* instead of entering the bay to the points *b* and *c;* also in case a barrier beach migrating toward the shore encountered the island and headlands in its progress.

If several islands instead of one were involved in the foregoing cases, more complex types of backward and lateral tying would result. Nantasket Beach represents a complicated case of both lateral and backward tying, involving for the most part prograded lateral tying bars of the types *b* and *c*, Fig. 2.

THE PRESENT FORM OF NANTASKET BEACH

The principal topographic features of Nantasket Beach are shown on the accompanying map (Fig. 8) based on a chart of Boston Harbor prepared by the United States Coast and Geodetic Survey (No. 246, C. & G. S. Boston Harbor, 1907). The larger features appear on the chart, but we have added the details of smaller beaches, wave-cut cliffs, etc. The irregular hills in the southern part of the map are composed of much altered sedimentary and igneous rocks which are very resistant and yield but slowly to the attack of the waves and weather. All other elevations on the map represented by contours are drumlins more or less eroded by wave action. The lower areas, including the lower ridges indicated by short hachures, are practically all of beach material; the exceptions consist of low areas of till between certain drumlins located close to each other, beach sand gathered into small dunes by the wind, and some deposits in swampy areas to be considered later. If we except the rock above mentioned, we may properly say that the features of the Nantasket region are due to marine action upon drumlins; for the effects of stream action and wind action are so slight as to be negligible.

The drumlins.—In describing the present form of the Nantasket drumlins it will be convenient to consider them in the order of their preservation from marine erosion. The letters in parentheses refer to the respective drumlins on the map, Fig. 8. The best preserved of the Nantasket drumlins is a small one called Hampton Hill (H),

located in the southern part of the region, back of the beach. It has been slightly cliffed by the harbor waves, on the southwest, but is otherwise practically in the same condition as when the ice left it. Nantasket Hill (N) at Hull, also called Telegraph Hill, is another drumlin which has suffered but little erosion; it is slightly cliffed on the south. Thornbush Hill (T), just west of Nantasket Hill, is somewhat more strongly cliffed, but retains its initial form to a marked degree. The erosion has taken place at the southwest side. Sagamore Head (Sa), near Hampton Hill, preserves a nearly perfect outline except for a pronounced cliff on the the northeast side and a minor cliff on the north and west. The main cliff is well back from the present shoreline, and has evidently not been touched by the waves for many years.

North of Sagamore Head is White Head (W), a drumlin which retains its initial form fairly well on the south, although a slight cliffing is noticeable there; but which has a remarkable strongly curved cliff cut into its northern side (Fig. 11), and smaller cliffs on the northeast and east. Like the northeast cliff on Sagamore Head, the cliffs on the north and east sides of White Head are well back from the present shoreline and have long remained untouched by the waves. West of White Head are several low drumloidal hills, connected by lower areas of till and cliffed on both the north and south sides. Great Hill (G), at Allerton, has a strongly marked cliff on the eastern end where the waves are still cutting into the hill, although not so effectively as formerly. There has apparently been a slight cliffing on the western end of Great Hill, also. Strawberry Hill (St), about half-way between Allerton and Sagamore Head, is in many respects the most remarkable drumlin in the district. Except for a short distance along the northwest side, it has been cliffed throughout its entire circumference; a rather inconspicuous cliff is developed along the north side, more prominent cliffs on the south and west sides, while the southeast face is a splendid marine cliff long ago abandoned by the waves (Fig. 3). In fact the only point where the sea still reaches the drumlin is along its southwest side. There is a marked escarpment on the northeast corner of the cliffed drumlin, but much of this is due to the removal of till for road-building. Professor Isaiah Bowman informs us, however, that a small nip existed there before

the excavations by man obscured the relations. It should be noted that the abandoned cliffs of Sagamore Head, White Head, and Strawberry Hill do not face in the direction of the present shoreline, but make pronounced angles with that shoreline, as shown by the map.

Quarter Ledge (Q) at Hull is a more than half-consumed drumlin, the marine cliff facing northward. Little Hill (L) at Allerton is of special interest because it is evidently but a small remnant of a drumlin (Fig. 10) on the northeast of Great Hill. It would doubtless have

FIG. 3.—Strawberry Hill, from the south, showing abandoned marine cliffs; the higher cliff faces southeast.

been completely removed by the waves ere this but for the protection afforded by a stone sea-wall constructed north and east of it to prevent its complete destruction. Skull Head (Sk) represents the final stage in the series, having been completely destroyed. This drumlin was situated to the northwest of Strawberry Hill, and so far as we can tell was probably of small size. It was apparently nearly destroyed by wave action from the west, the last remnant being removed by man and used as road material. Those who remember this drumlin remnant agree in describing it as having a gentle slope toward the east and a steep cliff facing west. The presence of great

bowlders near the supposed former site of this drumlin, the shape of the associated beaches, and the westward protuberance of the shoreline northwest of Strawberry Hill confirm the descriptions and location of the drumlin given by the inhabitants.

West of Nantasket Beach there are many drumlins more or less cliffed by marine erosion. On Nantasket Beach are drumlins in all stages of marine erosion, from slight cliffing to almost complete destruction. East of Nantasket Beach no drumlins are encountered. The suggestion is very strong that the sudden cessation of drumlins to the east is due to the complete removal of formerly existing drumlins by marine erosion. As will appear later there is strong evidence in favor of this interpretation.

The beaches.—Under this head are described the various spits, connecting bars, beaches, etc., both ancient and recent, which make up the composite feature called Nantasket Beach.

The beaches at Hull present no striking characteristics. The cliffed drumlins of Nantasket Hill, Thornbush Hill, and Quarter Ledge are close together, connected by lowland areas of till, and the cliffed portions are bordered by a narrow, sometimes bowldery beach. A sand spit, called Windmill Point, is strung out toward the west, probably under the influence of tidal currents passing through Nantasket Roads. This group is connected with Allerton by a bar believed to be the result of simple backward tying from Great Hill and Little Hill. The appearance of a Y bar is due to a railroad embankment built across the end of the bay back of Great Hill in order that the track would not have to be placed in the very exposed position on the seaward side of the Allerton drumlins. The protuberance of beach material from the northwest side of Great Hill is explained later.

From Allerton Great Hill on the northwest to the rock hills of Cohasset on the southeast a relatively straight beach borders the present shoreline. Back of this modern beach one observes parallel ridges of sand, gravel, and cobbles, in all respects similar to the higher part of the present beach which is still being acted upon by the waves. Still farther back the ridges become less prominent, until in the central areas of the Nantasket lowland they are scarcely perceptible. Moreover, they are no longer parallel to the modern

beach, but are strongly curved, concave toward the east. At the extreme west, however, these curved beaches become prominent features once more and are as high in places as the modern beach.

If we examine the older beaches more carefully, we note several significant points. Just south of Allerton Great Hill the high and prominent westernmost beach, which we may call West Beach, is intersected by the modern beach. West Beach does not touch Great Hill and from the curvature of the beach it seems hardly probable that it connected with the former seaward extension of Great Hill. At its southern end West Beach ties to the northwest side of Strawberry Hill, just in front of the only part of the hill which has no bordering marine cliff. From the western side of the beach projects the protuberance of the Skull Head area, which destroys the otherwise symmetrical curve given to this portion of the harbor shoreline. Of the beaches which intervene between West Beach and the modern beach, a few connect with Strawberry Hill, others curve eastward as if to connect with something formerly situated in front of Strawberry Hill, and still others pass in front of the hill to connect with White Head or Sagamore Head farther south; while at the north all converge toward the intersection of West Beach with the modern beach, merging with the former or being cut off by the latter. The waves from the harbor are now attacking West Beach north of Skull Head, giving it a steeper western face, cutting off part of the western convexity, and building a small subsidiary beach toward the north. This attack of the harbor waves upon a beach formerly constructed by the powerful Atlantic waves has become so effective that sea-walls have been built in places to prevent further destruction of the old beach.

South of Strawberry Hill the relations are much the same, except that the beaches are less distinct and less regular in outline. The equivalent of West Beach does not connect directly with Strawberry Hill, but is truncated by a more recent beach or spit which extends southward from the southwest end of the great cliff on Strawberry Hill. The older main beach curves rather strongly southwest, continues south and southeast in much broken and complicated ridges, and finally spreads out in a broad, indefinite plain of beach material near the western end of White Head. The most prominent beach in this vicinity is one which extends from the eastern point of Straw-

berry Hill to the eastern end of White Head, and on which the County Road is located for much of the distance between the two hills. Both east and west of the County Road Beach are some fairly well-marked beaches, more or less obscured by sand dunes, especially toward the east. Two of the older beaches between White Head and Sagamore Head are especially prominent, and are practically straight. Both north and south of Strawberry Hill the beaches in the central areas, midway between the drumlin hills, are often so low and indistinct as to be nearly or quite imperceptible. In places the detection of the beaches is made easier by a difference in the grass and other vegetation growing on the beach ridges and in the intervening depressions.

THE INITIAL FORM

In our attempt to reconstruct the initial form of Nantasket Beach, we have appealed to three sources for information: (1) Some of the older inhabitants who recall the appearance of the beach in earlier days; (2) Old maps and charts of the region; (3) The principles of shoreline development applied to the interpretation of the present forms.

Shoreline changes take place with comparative rapidity, and in some cases a man may live to see profound alterations in the outline of the coast on which he lives. Some residents of Nantasket speak of a time when the sea used to come in to the present location of the County Road. It must be remembered, however, that people are apt to be impressed by the unusual, and that some long-past transgression of exceptional storm waves far across the present beach may be responsible for the impression that the sea is now farther removed from the road than it was fifty years ago. As late as 1898, during the "Portland Storm," breakers crossed the railroad track, which is well back from the present beach. In regard to the former location and general appearance of the remnant of Skull Head drumlin, now completely lost, the descriptions of the older inhabitants agree fairly well, and are corroborated by the physiographic evidence.

The old maps and charts of the region afford some evidence as to the general outline of the beach in earlier years, but prove to be too inaccurate to justify any conclusions as to recent changes in outline. A chart prepared by the United States Coast and Geodetic Survey in

1846 differs in minor points from the more recent charts of the same area, and a comparison of the two might be expected to show changes in the shoreline since 1846. Indeed, such a comparison has been made in connection with a study of cliff retreat at Allerton Great Hill and an estimated retreat of about two feet a year has been inferred on the basis of the comparison. A careful study of the two charts in the light of the geological features of the region makes clear the fact that one or both of them are too inaccurate to warrant any conclusions as to changes in shoreline based on such evidence. For example, it appears from the charts that the shoreline along the southeastern corner of Allerton Great Hill is farther east today than it was in 1846. Now the shoreline at this point is formed by the cliffed face of the hill, and since this hill is a drumlin which could not have been built forward since the glacial epoch, the charts are manifestly not sufficiently accurate to be used in determining recent changes in shoreline. On the other hand, it should be noted that the chart of 1846 indicates a shoreline so nearly like the present shoreline as to warrant the conclusion that the sea has not been materially closer to the County Road in the last sixty years than it is today, except during unusual storms. Indeed, a chart of Boston Harbor published in the fourth part of *The English Pilot* in 1709, while not accurate in details, seems to show that no pronounced changes in the shoreline of Nantasket Beach have occurred in the last two hundred years.

The application of the principles of shoreline development to the interpretation of the present form of Nantasket Beach offers the only means of determining the initial form of the beach. We believe that by this means it is possible to determine with a fair degree of certainty the geography of the Nantasket region before the present beach came into existence. The problem involves the restoration of the lost drumlins of this portion of Boston Harbor.

There is little difficulty in the restoration of those drumlins which retain their initial form to a considerable degree. The existing drumlins of the Boston district are of the same general type, none of them resembling the greatly elongated type found in some parts of New York. It is possible, therefore, to complete the outlines of Thornbush Hill (T) and Nantasket Hill (N) at Hull, Great Hill (G), Strawberry Hill (St), White Head (W), Sagamore Head (Sa), and Hampton

Hill (H) without danger of appreciable error. This has been done in Fig. 4, the restored portions being indicated by broken lines. Where more than half of a drumlin has been destroyed, the restoration cannot be made with the same degree of certainty, and we recognize that the location and size of such drumlins cannot be determined with absolute precision. The margin of error is not so large as materially to affect our problem, and the restorations of Quarter Ledge drumlin (Q) and Allerton Little Hill (L) in Fig. 4 (restored portions in broken lines) are believed to be essentially correct. The position of Little Hill will account for the peculiar protuberance of beach material northwest of Great Hill, if we agree that a spit trailing back from Little Hill by the action of waves and currents through Nantasket Roads would have a form somewhat similar to that of Windmill Point (WP) in Fig. 8. The restoration of the drumlins which are wholly destroyed involves a larger chance of error, and each individual restoration of this kind must be carefully considered.

The first restoration of a drumlin now completely destroyed (complete restorations shown by dotted lines) is that of Allerton Lost Drumlin (AL). That this drumlin formerly existed is shown by the relations of West Beach. The beach does not connect with Great Hill at the present time, but is abruptly cut off by the present shoreline a short distance south of Great Hill. That this beach formerly continued toward the east seems clear. It is equally clear that the seaward continuation of the beach would not connect with the seaward continuation of Great Hill, unless we imagine the beach to have been bent sharply northward. This last assumption is contrary to what we should expect in a beach as well developed as West Beach, has no evidence to support it, and is one which we are not permitted to make arbitrarily. The precise location of the drumlin with which West Beach must have connected cannot be determined with certainty, nor can its size be inferred; but that it occupied some such position as is indicated in Fig. 4 there would seem to be little doubt. It is not permissible to consider West Beach connected with the eastward extension of Little Hill, for this would require a marked northward bend in the beach, or the reconstruction of Little Hill on too large a scale.

It will be convenient to consider the restoration of Skull Head

drumlin (Sk) next, as certain features connected with it will aid us in other reconstructions. The location of this drumlin is made clear, as already noted by the peculiar protuberance back of West Beach northwest of Strawberry Hill, by the occurrence of large bowlders along the shoreline at this point, and by the historical evidence. That the drumlin was small is indicated by the fact that it has been completely removed, although in a relatively sheltered position, and by the further evidence that this removal was accomplished mainly by the harbor waves, it being stated by those who remember the drumlin that the eastern slope was not cliffed, while the western face was a distinct marine cliff. The last remnant of this drumlin was removed by man in recent years. The location and size of Skull Head drumlin are believed to be essentially correct.

An examination of the great southeast cliff on Strawberry Hill shows that the cliff was formed by waves coming from the southeast, and not from the northeast, the direction of the present wave attack. The fact that a sharp angle on the cliffed drumlin projects forward on that part of the hill which would be most exposed to the direct attack of the waves had no other drumlin existed in front of it to protect it, confirms the opinion that the restoration of a drumlin must be made in the vicinity of the shallow area off-shore known as Strawberry Ledge. This we have called the Strawberry Lost Drumlin (SL). As will appear later, the former presence of a drumlin at this point accounts for the northeastern angle (recently blunted by excavations for road material) of Strawberry Hill, the small amount of cliffing on the north side of the hill, the eastward curve of the beaches northeast of the hill, the direction of the splendid southeast cliff, and a certain feature of West Beach to be considered in the next paragraph. Whether the shallow area at Strawberry Ledge has any connection with the Strawberry Lost Drumlin we are unable to say, but that the drumlin must have been located near this spot seems clear.

As has already been noted, Skull Head drumlin (Sk) was apparently not cliffed on the east, or was so slightly cliffed as not to attract the attention of persons who did notice the cliffing on the west. Yet this drumlin must have occupied a position fairly well exposed to the waves of the Atlantic, unless some protection from those waves was afforded by drumlins or beaches farther east. It should be noted

also that West Beach is unusually high and broad, the modern beach at the east alone showing the same strength of development. In order that the waves should build a beach so extensive and so well developed, they must either have acted on the ancient West Beach shoreline for a long period of time, or must have been rapidly supplied with an immense amount of material previously reduced to a condition ready for beach construction. That the waves did not act for a long period of time in the vicinity of the ancient West Beach shoreline is shown by the absence of any considerable cliffing on the east end of Skull Head drumlin and the north side of Strawberry Hill. It is evident, moreover, that the large amount of material in West Beach could not have been supplied by the cliffed portions of the existing drumlins in that vicinity so it must have come from drumlins long ago destroyed, or from the sea bottom. We believe that the most probable condition which will account for all the facts is the former existence of a beach or series of spits more or less completely closing the space of open water between Strawberry Lost Drumlin and Allerton Lost Drumlin, thus forming a barrier which protected Skull Head drumlin and Strawberry Hill from wave action. The construction of this barrier was probably facilitated by the existence of another drumlin in the vicinity of the shallow area east of Bayside, and we have called the restoration of this drumlin (Fig. 4) the Bayside Lost Drumlin (BL). As will appear in the next section, the present relation of beaches and cliffs strongly suggests that a drumlin located in the vicinity of the Bayside shallow maintained the barrier so long as any part of the drumlin remained; but that with the complete removal of the drumlin the barrier was broken through, the accumulated débris swept rapidly back to the present position of West Beach, still protecting the east end of Skull Head drumlin but exposing a large part of the north side of Strawberry Hill to the waves which formed the low cliff we observe today.

The highly peculiar character of the cliffing on the north and northeast sides of White Head drumlin can be explained only by the restoration of a drumlin northeast of White Head. This we have called the White Head Lost Drumlin (WL). Its precise location cannot be determined, but it must have been close enough to White Head to control the marked curvature of the White Head cliff and the

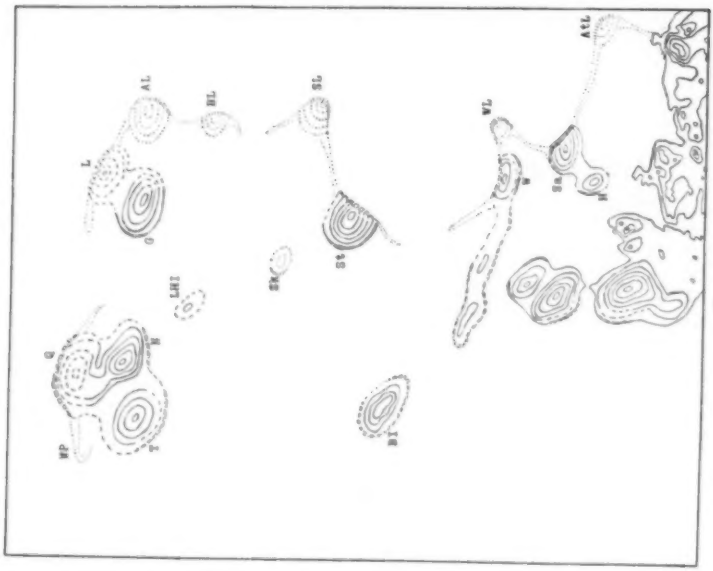
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FIG. 5

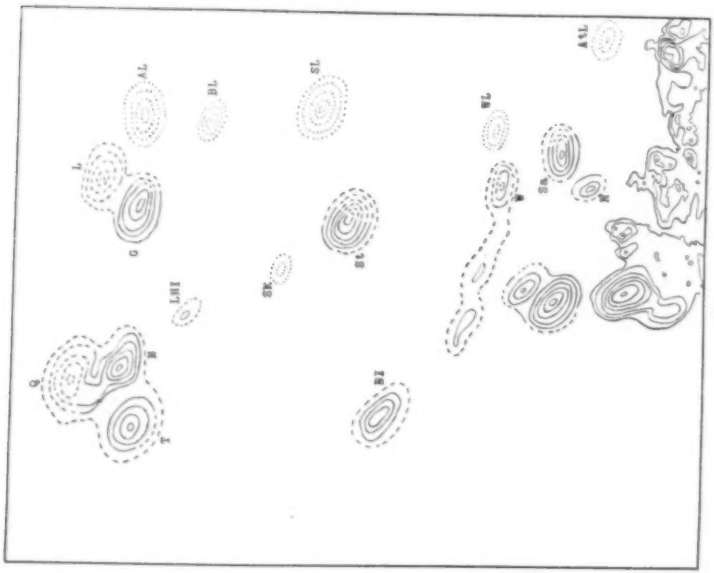
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FIG. 4

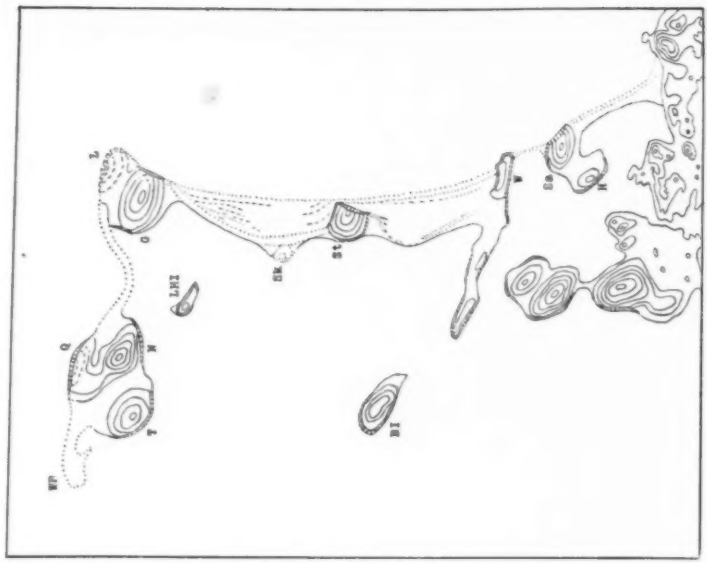

FIG. 7

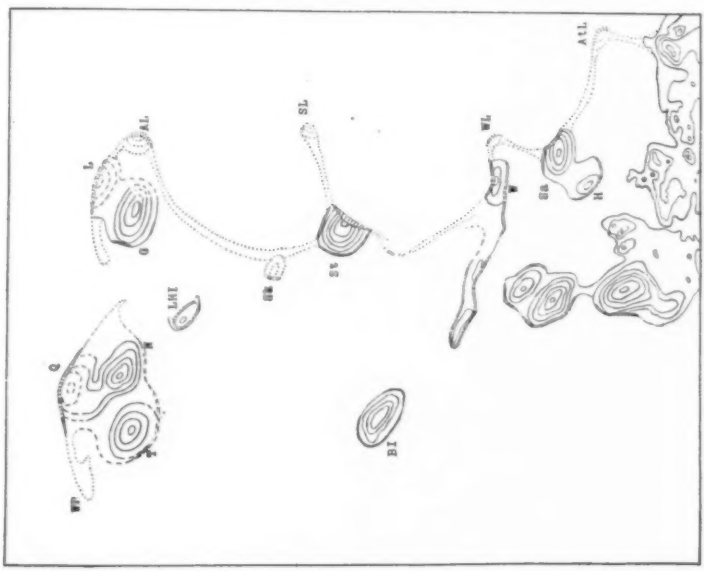

FIG. 6

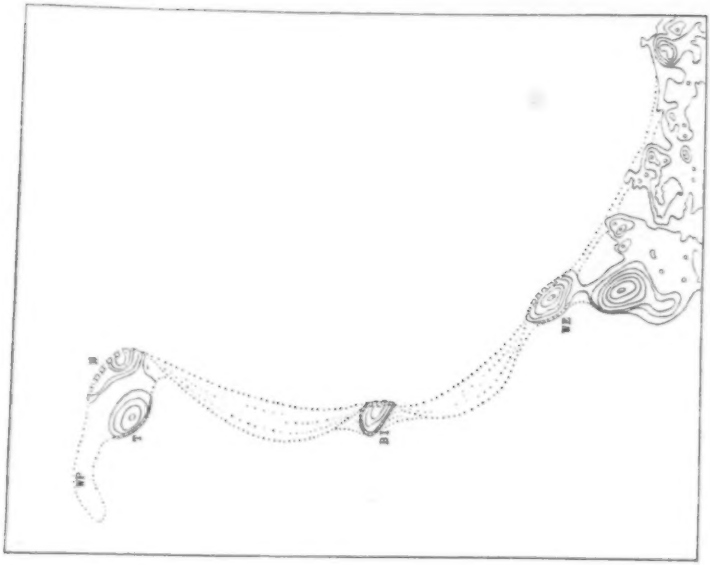

FIG. 9

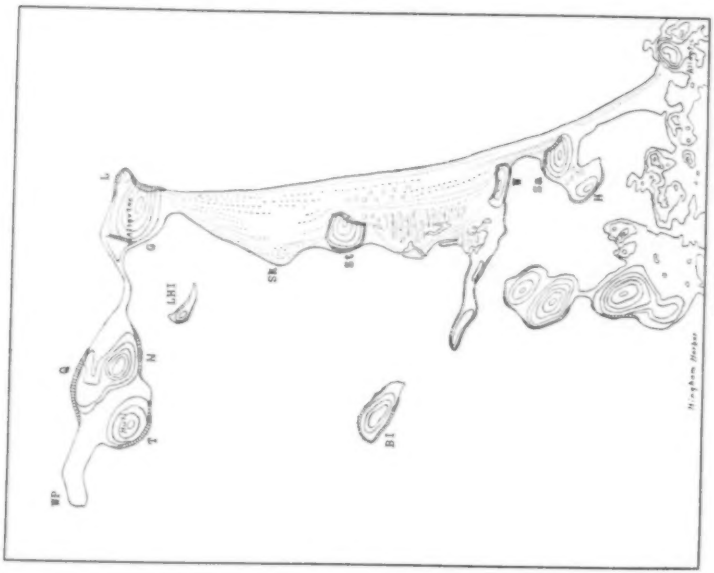

FIG. 8

less marked but distinctly curved cliff on the northeast side of Sagamore Head. The position assigned to it in Fig. 4 cannot be far from correct. The character of the Sagamore Head cliff, just referred to, necessitates the restoration of another drumlin to the southeast. Unless this drumlin existed somewhere in that region, affording protection to the southeast corner of Sagamore Head, it is difficult to understand why the latter was not cliffed directly from the east, and why the cliff is concave instead of convex. A shallow area north of Atlantic Head may have been the location of this drumlin as shown in Fig. 4. It is possible, however, that it may have been nearer Sagamore Head. We have called this restoration the Atlantic Lost Drumlin (At L).

This completes the restorations which seem required by the present forms of cliffs and beaches. That other drumlins may have existed in the region is, of course, possible; although the former existence of many more in the immediate vicinity of the Nantasket area would doubtless be indicated by peculiar alignments of cliffs on the remaining drumlins, or by the relations of the beaches. That additional drumlins may have existed still farther east is quite possible, but the data necessary for the reconstruction of such easternmost drumlins would be recorded only on drumlins and in beaches since completely destroyed. So far as the present problem is concerned the conditions shown in Fig. 4 may fairly be taken to represent the initial one of a series of developmental stages which we will now endeavor to follow until the present form of Nantasket Beach is reached.

THE DEVELOPMENT OF NANTASKET BEACH

In Fig. 5 we have endeavored to represent the conditions which probably existed in the Nantasket region at a much later stage than Fig. 4. The Allerton, Bayside, and Strawberry Lost drumlins have been much eroded by the waves and the material removed from them has been built into spits or connecting bars, which together with the remaining portions of the drumlins form a barrier to protect the east end of Skull Head drumlin and the north side of Strawberry Hill from any appreciable erosion. From Strawberry Lost Drumlin a bar ties backward to Strawberry Hill, protecting the northeast corner of the hill and helping to determine the direction of the wave attack which

is producing the southeast-facing cliff. That Strawberry Hill and White Head were exposed to strong wave action while Skull Head and Great Hill were well protected is evident from the splendid development of the ancient marine cliff on the two former. White Head Lost Drumlin is much eroded, but still serves to determine the character of the cliff on the north side of White Head, and at the same time effectually to protect the eastern end of the same. Sagamore Head has been cliffed on the northeast, the character of the cliff being

FIG. 10.—Little Hill, the remnant of an almost completely consumed drumlin.

determined by the position of White Head Lost Drumlin and Atlantic Lost Drumlin, and the bars tying back from them. Atlantic Lost Drumlin is much eroded, and in addition to being connected with Sagamore Head has a short bar connecting with the rock cliffs just south.

Allerton Little Hill and Quarter Ledge drumlin, facing the main channel to the north, have been considerably eroded, while even the better-protected drumlins have, as a rule, been cliffed slightly, especially on their more exposed sides.

It is evident that some latitude is allowable in the restoration of

certain of the features shown in the figure, without affecting the validity of the general interpretation here set forth. For example, the precise shape and location of the sand spits cannot be ascertained; and Atlantic Lost Drumlin might be nearer Sagamore Head, in which case the long bar connecting the two might be altogether absent, or represented by short spits or a short bar. We have indicated, however, those conditions which we consider most probable and the main features of the drawing are believed to be essentially correct.

Fig. 6 represents a later stage than Fig. 5. The complete destruction of Bayside Lost Drumlin has allowed the material formerly accumulated in its vicinity to be swept back to the Strawberry Hill–Skull Head region, and to be rapidly constructed into the prominent West Beach. At the north this beach still connects with the remaining portion of Allerton Lost Drumlin, thus accounting for the failure of this beach to touch Allerton Great Hill, a relation which is very distinct at the present time. At the south the connection with Strawberry Hill was far enough west to allow a slight cliffing along much of the north side of the hill. The absence of a pronounced cliff at the northeast corner of Strawberry Hill previous to recent excavations, and the eastward curve of some of the old beaches northeast of the hill (Fig. 3) indicate that a remnant of Strawberry Lost Drumlin still survived at the period represented by Fig. 6 and even later, preserving the backward-tying bar until West Beach was considerably prograded. Between Strawberry Hill and White Head spits or a curved bar nearly or quite close the space of open water, although the irregular character of the gravel ridges now observable at this point suggests that the bar may have been repeatedly broken through during heavy storms. The retreat of the shoreline on the southwest side of Strawberry Hill has caused the older beach ridge to be truncated by a sand spit now forming. Other minor developments are indicated, including the continued cliffing of various hills, and the growth of Windmill Point and other smaller spits.

In the stage represented by Fig. 7 the present characteristics of Nantasket Beach begin to be more easily recognizable. Allerton, Strawberry, White Head, and Atlantic Lost drumlins have all been completely removed. Prograding has gone on actively in the two re-entrant curves north and south of Strawberry Hill, the shorelines

thus migrating eastward until a single beach describes a very gently concave curve from Allerton Little Hill to White Head. That the process of prograding was relatively rapid is indicated by the small size of the beaches in the inland areas north and south of Strawberry Hill. In places these beaches are almost imperceptible, and south of the hill it seems probable that the change in the position of the eastern shoreline from the westernmost beach to the County Road Beach was made without the formation of complete intermediate beaches. That the prograding had proceeded quite far, in the northern re-entrant at least, before the removal of the bar connecting Strawberry Hill with Strawberry Lost Drumlin, is shown by the development of faint beaches just north of the hill, curving eastward so strongly that they would pass in front of the restored portion of the hill if they were prolonged. These beaches must have been formed before the bar was destroyed. After the complete removal of Strawberry Lost Drumlin and the destruction of the bar, the ends of these beaches were eroded, as shown in Fig. 7, and the eastern angle of Strawberry Hill was slightly cliffed by the waves. In this manner the portion of the shoreline which had been prograded with reference to the Strawberry Lost Drumlin and bar, was retrograded until brought into harmony with the conditions existing after the destruction of drumlin and bar. Before the waves could seriously affect the the corner of Strawberry Hill the prograding of the entire beach (from Allerton Little Hill to White Head) as a single unit carried the shoreline eastward beyond the base of the hill. The prograding of the beach appears to have been connected with the retrograding of the headlands at Allerton and the removal of Whitehead and Atlantic Lost drumlins. As Allerton Lost Drumlin, Little Hill, and Great Hill have been cut back, the beaches to the south have been built forward, the point of no change, or fulcrum, being just south of the east end of Allerton Great Hill. The lack of a complete series of beaches south of Strawberry Hill may be connected with a more sudden westward migration of the southern end of the shoreline upon the disappearance of Whitehead and Atlantic Lost drumlins, and a consequent sudden eastward movement of the zone of wave building just north of Whitehead drumlin. As soon as the eastward migration of the beaches allowed the shoreline to clear the hill, the successive

beaches appear to be more or less continuous from Allerton to Whitehead. The remaining changes indicated on the drawing need but little comment. The removal of White Head Lost Drumlin, together with the formation of the County Road Beach, has resulted in the cliffing of White Head on the east and northeast, while the removal of the Atlantic Lost Drumlin has allowed the connecting bars to swing back and form a single bar which unites with the rock cliffs at Atlantic Head.

The next stage in the development of Nantasket Beach is that of the present, represented in Fig. 8. The principal change from the preceding stage consists in the prograding of the beach until it makes an unbroken, gently curved shoreline from Great Hill to Atlantic Head; the further cliffing of White Head at the eastern end and the abandoning of the cliffs on White Head and Sagamore Head by the waves as the shoreline migrated eastward; the complete removal of the Skull Head drumlin, partly within recent years; the filling-in of the small bay on the south side of Windmill Point, largely within historic times; and further erosion of all the drumlins still exposed to wave action.

In Fig. 9 we have attempted to represent a possible future stage in the development of Nantasket Beach. At the present time the most effective wave erosion is concentrated upon Great Hill and the small remnant of Little Hill. But these hills control the future of the beach, the erosion of the rocky mainland at the southern end being so slow as to be practically negligible. Heretofore the retrograding of these hills has caused the prograding of the beach; at the present time, however, a condition of equilibrium prevails, and a further cutting-back of the hills must result in a cutting of the beach also. With Great Hill gone, the beach would connect Nantasket Hill, Little Hog Island, Strawberry Hill, White Head, and Sagamore Head. Strawberry Hill would be at an exposed angle of this beach and would soon be destroyed. Little Hog Island and White Head would be more exposed than before, providing the former had outlasted Strawberry Hill. Sagamore Head and Hampton Hill would take their turns in controlling the position of the beach until completely reduced by the wave attack. The drumloidal extensions west of White Head and the Hull district at the north will be the last remnants of Nan-

tasket Beach to survive, and of these two the Hull district will probably last much longer. If this interpretation is essentially correct, the relations in the Nantasket region will, in the remote future, resemble those indicated in Fig. 9. It is possible that the connecting bars may be broken through by the sea in one or more places, and that sand spits may replace the bars here shown. This will depend on local conditions of water depth and other factors which cannot be predicted.

FIG. 11.—Whitehead Drumlin, showing concave marine cliff on north side.

At present the area here shown is shallow, and favors the building of bars as indicated.

The protection of Great Hill is the key to the preservation of the entire Nantasket Beach district. A sea-wall has been constructed for the preservation of Little Hill, and this, of course, means protection to the adjacent areas of Great Hill. By such protective measures man may indefinitely postpone the normal changes which Nature would effect in the Nantasket area. It is interesting to note that man has begun his work in controlling the development of Nantasket Beach just at the time the beach has reached the greatest size which Nature could probably give it. Heretofore the beach has been increasing in

area. Hereafter the normal development of the beach, unless arrested, would result in decreasing its area.

CHANGES OF LEVEL IN THE NANTASKET AREA

Much has been written concerning possible elevations and depressions of the Massachusetts coast since the glacial epoch. The evidence is often unsatisfactory and contradictory, but is thought by many to indicate a gradual subsidence at the rate of approximately one foot in one hundred years. Professor Crosby believes that some of the drumlins, which now show no marked cliffs facing toward the Atlantic, were strongly cliffed before Nantasket Beach was completed, and that subsidence has carried these cliffs under water. "This view relieves us of the necessity of imagining a cordon of drumlins outside of the present beach which have been completely washed away, although it is not improbable that Harding's Ledge and the Black Rock Islets are the foundations of such vanished drumlins" (Crosby, p. 170). As we have shown above, there is abundant evidence that a number of drumlins did formerly exist outside of the present beach, and that these drumlins and their associated bars and spits effectively protected drumlins back of them from erosion. No subsidence is required to account for the lack of cliffing on the eastern ends of drumlins back of the present beach, and no evidence of submerged marine cliffs has ever been found.

It seems to us quite possible that there may have been a considerable depression in the Boston region since the glacial epoch; and that there may have been a very recent depression *of small amount* at the calculated rate of one foot in one hundred years. But that there has been any marked change in the relative position of land and sea during the last thousand years or more seems to us absolutely incompatible with the evidence furnished by Nantasket Beach. West Beach, as has already been pointed out, is similar in size and elevation to the beaches being formed along the present eastern shore of the Nantasket area. Had there been marked depression since the formation of West Beach, that beach would now be very low, possibly completely submerged. Had marked elevation occurred, West Beach should be relatively high, and other evidences of elevation should appear along the western margin of this beach. The close

similarity between the oldest and latest beaches in the Nantasket area proves that the sea stood at about the same height when the two were formed. The intervening beaches are often low, because of the rapidity with which the shoreline was prograded for a time; but County Road Beach is strong and high, and may be compared with West Beach and the recent beaches.

The duration of this still-stand of the land may be roughly calculated. Judging from old maps, there has been no marked change in the width of Nantasket Beach during the last two hundred years. Judging from the rate of cliff cutting in various drumlins in the vicinity of Boston as determined by surveys extending over forty years or more, the length of time required for the removal of those portions of drumlins which have disappeared since the early cliffing of Strawberry Hill and Whitehead and the formation of West Beach, with liberal allowance for relatively rapid cutting of drumlins well exposed to the sea, could scarcely have been less than one thousand years, and was probably two or three thousand years. We conclude, therefore, that there have been no marked changes in the relative position of land and sea in the Nantasket area during the last thousand years at least.

CONCLUSION

The form of Nantasket Beach presents a variety of complicated phenomena which, when carefully studied, enable us to reconstruct with reasonable certainty the history of the development of the beach. It appears that the present form of the beach is not due to the accidental tying-together of a few islands without system, but represents one stage in a long series of evolutionary changes which have occurred in orderly sequence and in accordance with definite physiographic laws. Perhaps nowhere in the world can features of beach development be better studied than in the area here under investigation. Certainly nowhere in the literature is recorded an example of so complicated a shoreline preserving the records of its past development with such fidelity.

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THE AGE OF THE EARTH AND THE SALTNESS OF THE SEA

H. S. SHELTON

Since the discovery of radioactivity, any estimation of geologic time from the process of secular cooling, or from calculations of the age of the sun's heat has become a process of very doubtful validity. That being so, enhanced interest now accrues to any method not based on these data. One of the most instructive of these is that of Professor Joly[1] based on the saltness of the sea. But, standing as it does on its own merits, and without collateral support, it is more than ever necessary to examine carefully the foundations on which it is based.

The analysis of rocks shows clearly that the proportion of sodium in the sedimentaries is much smaller than in the igneous rocks. The natural inference from this is that the balance is to be found in the ocean in the form of salt. Assuming these premises and a fairly uniform rate of erosion, the estimation of geologic time is reduced to a process of simple division. It is only necessary to find the total quantity of sodium in the sea and the amount brought down by the rivers each year. This, with some corrections, is Professor Joly's method. The corrections, according to his estimate, are not considerable and his calculation works out to something less than 100 millions of years.

The data for the two principal premises are derived from Sir John Murray.[2] This worker has carried out numerous investigations on ocean depths and has also made estimates of the amount of solvent denudation. That these are in the main fairly accurate can hardly be disputed; but, as applied by Professor Joly to an entirely different purpose, they are open to a number of criticisms.

For our present purpose we will accept Sir John Murray's estimate of the amount of the sodium in the sea; but the amount which enters

[1] *Trans. Royal Society Dublin*, Vol. VII, pp. 26 f.

[2] See *Scottish Geographical Magazine* (1887), and elsewhere.

into it each year is a much more doubtful quantity. Into all the sources of error it is not possible to enter here; but the following short summary will show that these are very great.

In the first place we must remember that sodium is a minor constituent in river waters. It is also, as every chemist knows, the most difficult of all to determine. Anyone who is acquainted with the many possibilities of error implicit in the process of boiling down considerable quantities of river water, removing all the other constituents in order to find in the end possibly two or three parts per million of sodium, will know that very little reliance should be placed on this part of an ordinary water analysis. In order to obtain results of any value for this constituent, great care and special precautions must be taken. So far is this from being the case in the average analysis, especially the older ones from which Sir John Murray's tables are constructed, that all the alkali metals are commonly determined together and stated as sodium and potassium.

Once more, Professor Joly makes an entirely inadequate allowance for cyclic salt. Sea salt, especially in stormy weather, continually passes into the air, is brought down by the rain, and is deposited in other ways. This is washed into the rivers and thus reaches the sea once more. Another form of cyclic salt is that known as fossil sea salt. This was deposited with the other constituents in the sedimentaries and is once more set free by erosion. As none of the ordinary rocks (with the exception of salt beds) contain any appreciable proportion of chlorine, it is highly probable that the greater part of the chlorine in river waters is cyclic in some form or other. This particular aspect has already been the subject of some controversy, and Professor Joly has admitted that he has probably underestimated the amount of cyclic salt; but he meets the difficulty by stating that there is a considerable preponderance of sodium in the river waters above the chlorine, and that, even assuming that all the chlorine is cyclic, the estimate of geologic time is not thereby raised to more than one hundred and forty millions of years.[1]

But, by this admission, the whole calculation is made to rest to a much greater extent on the minute accuracy of sodium analyses, which, as we have already seen, does not exist. To show what differ-

[1] See discussion between Professor Joly and Mr. Acroyd, *Chemical News* (1901).

ences small errors can make, it is interesting to note that more recently another worker, M. Dubois, has made fresh calculations, using only the more accurate sodium analyses, and has obtained as the result four hundred millions of years.[1] I, for one, should not like to state dogmatically that one or other of these results is accurate; but certainly the calculation of Professor Dubois is the more reliable of the two. It is more instructive to note the reason why such diverse estimates are possible. This can be seen by anyone who refers to the original paper and makes a few simple calculations.

According to Sir John Murray's data, the percentage of sodium in river waters compared with the total dissolved solid is 3.47, that of chlorine 1.85.[2] Professor Joly's calculation assumes 10 per cent. of the chlorine to be cyclic. If we assume the amount of sodium to be 2.47 per cent. (an amount of error not at all unlikely to occur in these analyses, especially if calculated in a rough statistical way), and the more probable quantity of 90 per cent. of the chlorine to be cyclic, our estimate would be raised to two hundred and fifty millions of years. If the sodium were but 1.5 per cent. of the total solid, the estimate would be fifteen hundred and seventy millions of years. As we have seen, M. Dubois' estimate was four hundred millions of years, but he has reached such a point in the calculation that a very small error would make a great difference in the result. From such considerations as these we can understand the uncertainty of any such estimate on present data. It is to be hoped that, in the future, chemical analysts will pay special attention to this problem of the proportion of sodium, and that, in this way, more accurate data may be obtained.

Nor must it be assumed that, however accurate may be the data, this problem can be regarded as solved. There still remain a number of theoretical objections. The method assumes approximate uniformity in this process of the conveying of sodium to the sea. It also assumes that the sodium which reaches the sea never returns to the sedimentaries. Neither of these assumptions, though probable, can be regarded as established. Our knowledge of geological chemistry is certainly not sufficient to enable us to say that none of the

[1] *Proc. Amsterdam Academy* (1902).

[2] See Clarke, *Data of Geochemistry*, p. 88.

sodium in the sedimentaries had its origin in the sea. Then the problem of salt beds must also be considered. That a considerable proportion of the salt deposited in lakes is cyclic, and had its origin in the sea may be regarded as established. But what would happen if such a salt bed were subject to metamorphic action? It is obvious that not only would the sodium enter into the composition of the metamorphic rock, but that it would do so out of all proportion to the chlorine. Such a volatile constituent as chlorine is bound to be evolved in the form of some compound of lower boiling point than salt. Indeed, is it not possible that a proportion of the large quantities of hydrochloric acid, ammonium chloride, and aluminum chloride evolved during volcanic action may have their origin in this manner? If this speculation were true, it is quite possible that the cyclic sodium, using the term in its widest significance, might exceed the cyclic chlorine, and that the calculations would be still further vitiated.

Without laying too great stress on this speculation, it must not be forgotten that uncertainties of this kind exist, and that the sea-salt method must not be regarded as of greater validity than those founded on pure geology. The method is liable to a number of uncertainties and it would not be wise to lay too great stress on this particular estimate. It is highly probable, however, that this method, when based on more accurate analyses, may act as a check on the results obtained from pure geology, from radioactivity, and from other lines of attack. Nor must it be forgotten that this method,[1] even if in the future it should be superseded, was the first serious attempt to get outside the vicious circle of the classical physical three methods, which have proved such a barrier to the progress of geologic thought on this fascinating cosmic problem.

[1] In making this statement, the interesting investigations of Mr. Mellard Reade on the evolution of carbonate of lime must not be forgotten. This may ultimately prove of greater value than the sea-salt method. Unfortunately, in his later years, this author published other methods, based on less reliable data, which gave a smaller minimum for geologic time. His most valuable work was thus forgotten.

Reviews

RECENT SEISMOLOGICAL LITERATURE

EMILIO BÖSE. "Los temblores de Zanatepec, Oaxaca, a fines de septiembre de 1902" (The Earthquakes of Zanatepec, Oaxaca, at the end of September in 1902), *Paragones del Institute Geológico de Mexico*, Vol. I, No. 1, 1903, pp. 1–19; pls. 1, 2.

EMILIO BÖSE. "A. Villafaña y Garcia y Garcia, El temblor del 14 de abril de 1907" (The Earthquake of April 14, 1907), *ibid.*, Vol. II, Nos. 4–6, pp. 135–258; 43 pls. and a table.

JOSÉ G. AGUILERA (Director). "Catalogo de los temblores (Macroseismos) sentidos en la Republica Mexicana durante los años de 1904 a 1908" (Catalogue of the Earthquakes—Macroseisms—Felt in the Mexican Republic during the Years 1904–8), *ibid.*, Vol. II, No. 10, pp. 389–467.

So soon as the Spanish-speaking peoples appreciate their opportunity in the direction of the investigation of earthquakes, it will be necessary for them to print the results of their researches in one of the better-known languages of sciences, or students of seismology must take up seriously the study of the Spanish language. Between northern Mexico and the southern extremity of the Andean System, is included one of the greatest earthquake provinces of the globe. The recent establishment by the Republic of Chili of a well-equipped seismological service, and the initiation by the Mexican government of an important serial publication largely devoted to earthquakes, may indicate that this time is not far distant. The new serial is issued by the Mexican Department of the Interior and apparently is a continuation under a new name and with slightly altered purpose of the *Anales del Secretaria de Fomento*, etc.

The report upon the Guerrero earthquake of 1897 is a valuable paper of 123 pages, 3 maps, 2 diagrams, and 38 halftone views showing ruined structures and broken ground within the area affected by the earthquake. The text treats in considerable detail of the topography and geology of the district, of the effects of the earthquake, of the character of the motion, and of the "foreshocks" and "aftershocks." Of very special value is a

list of the earlier earthquakes within the province, beginning with 1784. Seven pages are devoted to a list of data from instruments at foreign stations, and fifteen pages to a discussion (largely mathematical) of the depth of the earthquake centrum.

Seismologists will welcome the elaborate catalogue of Mexican earthquakes which is published in the last number of the series, with its earnest of further work along the same line.

HARRY FIELDING REID. "Seismological Notes," *Proc. Am. Philos. Soc.*, Vol. XLVIII, No. 192, 1909, pp. 303–12.

Under this somewhat unimpressive title Professor Reid has put forward an entirely new theory of the cause of earthquakes. In his own summary this theory is thus stated:

> Tectonic earthquakes are caused by the gradual relative displacement of neighboring regions which sets up elastic strains so great that the rock is ruptured: and that at the same time of the rupture no displacements of large areas take place, but there occurs merely an elastic rebound, to an unstrained position, of the lips of the fault extending but a few miles on each side of it.

This theory is visualized for the reader by diagrams representing two short wooden blocks joined by a thick layer of stiff jelly which has been divided by a sharp knife into two equal layers. The blocks being held together under slight pressure, they are given a shearing motion. The jelly is thereby deformed much as would be a rubber layer, and the friction between the jelly surfaces is reduced by a release of the pressure upon the blocks. The two jelly layers now suddenly resume their former unstrained attitudes with the production of a fault of lateral displacement at their plane of junction. This fault is supposed to simulate in its manner of formation the recent displacement along the California rift, and the theory will command attention, particularly, since Professor Reid, as a member of the California State Earthquake Commission, has been intrusted with the problems of mechanics involved in the recent earthquake displacements, and has in preparation the second volume of the report of the commission.

The value of the theory will be adjudged differently by different workers, but it seems safe to say that its assumptions are far too sweeping and that the theory in its present form would never have been devised had the study of any save the California earthquake led to its framing. Of all known earthquakes which have been accompanied by visible displacements in the surface of the ground, this one is unique by reason of the large

proportion of the lateral to the vertical component of movement. As already pointed out by several foreign critics, the report of the commission is decidedly provincial in that it fails to take any account of work already done upon earthquakes, and because all conclusions seem to have been reached as though no other earthquake had been known or studied. Probably the most distinguished geologist of the commission has said of the California quake: "That event was so far unforeseen that no seismologists were at hand and the duty of investigation fell, in the emergency, on a volunteer corps of geologists and astronomers" (*Science*, N. S., Vol. XXIX, January 22, 1909, p. 122). While no doubt accounting for the notably local aspect of the study, this hardly furnishes its excuse. The literature of the subject is large and for the most part easily accessible.

In his discussion in support of the theory advanced, Professor Reid says, "there is a consideration which seems almost decisive in its favor." This consideration is derived from trigonometric surveys made (I) 1851–65, (II) 1874–92, and (III) 1906–7 (after the great quake). These surveys show clearly that lateral displacements measured in feet occurred within the wide zone bounding the great rift and in both the intervals I–II and II–III. This result, it should be stated, is quite in harmony with modern views of earth displacments. What is needed, however, in order to prove Professor Reid's contention, is a determined lack of connection in time between displacements during much shorter intervals and the earthquakes which have been so frequent in the district. The crucial question to be decided is whether a movement of a portion of the earth's outer shell was true warping or was a displacement of individual parts *per saltum* by repeated small amounts. Reid's theory leaves the smaller and frequent *temblors* altogether unaccounted for.

The argument that the amplitudes of the displacements revealed in the trigonometric data are greatest in the vicinity of the rift and fall away rapidly from it, is without force, since we know that faults revealed in geological sections quite generally show distribution of displacement over a number of planes within a zone, and the trigonometric stations are here so widely separated as to furnish no crucial data. There is, however, one consideration quite out of harmony with the Reid theory. Rock slabs which, by slow and continued application of stresses, have been forced into warped surfaces have been found to take on a permanent "set" and do not return by rebound to their original attitudes. As already pointed out, the validity of the theory can be tested observationally through the frequent "location" of monuments in earthquake countries and comparison of the results with an accurate catalogue of local earthquakes.

SIEGMUND SZIRTES. "Seismogramme des japanischen Erdbebens am 21. Januar 1906," *Veröffentl. des Zentralbureaus der intern. Seismolog. Assoz.*, Serie A, Abhandl., Strassburg, 1909, pp. 1–50; 2 maps and 7 pls. of seismograms.

SIEGMUND SZIRTES. "Unifilares Horizontalpendel," *ibid.*, 1909, pp. 1–21; 2 pls.

C. MAINKA. "Eine neue seismische Untersuchungsplatte" (Teil I), *ibid.*, 1909, pp. 1–37; 3 pls.

SEIGMUND SZIRTES. "Katalog der im Jahre 1905, registrierten seismischen Störungen" (I Teil), *ibid.*, Kataloge, 1909, pp. 1–193; 1 map.

ADOLF CHRISTENSEN ET GEORG ZIEMENDORFF. "Les tremblements de terre ressentis pendant l'année 1905, *ibid.*, 1909," pp. 1–543; 21 text-maps and a world-map.

The above-listed publications issued from the Central Bureau of the International Seismological Association show what is being accomplished with the funds subscribed by the different contributing governments. The world-catalogue of earthquakes is alone a stupendous undertaking sure to furnish future seismologists with the data for broad and safe generalizations. The bulky volume covering the year 1905 is in two parts, one chronological in its arrangement, while in the other the earthquakes are arranged chronologically under each of twenty more or less arbitrarily chosen earthquake provinces. The maps which show the distribution of the quakes of 1905 are of especial interest and value.

One of the memoirs discusses a new seismograph of fairly simple construction which has been devised by Dr. Szirtes with the purpose of obviating defects which an extensive comparative study has shown to be common to many of the types now in use. Dr. Mainka's "New Seismic Testing Plate" is intended for use in testing seismographic apparatus of a wide range of design. Incidently, it may be mentioned, the plates of the paper give much the best representations of the Mainka Bifilar Conical Pendulum (a form now widely introduced in Germany) that have thus far appeared. Szirtes' monograph on the Japanese earthquake of January 21, 1906, differs widely from the ordinary earthquake report, in that an attempt has been made to bring the instrumental data into some relation to topography and geology. A graded intensity map of Japan shows a somewhat remarkable resemblance to the interesting geognostic map of Japan by the late Baron v. Richthofen. As a result of his study, Szirtes states the

following propositions concerning the propagation of the seismic energy of the earthquake:

1. The propagation is most rapid in the direction of the strike of the rock layers, and slowest perpendicular thereto.

2. Breaks (*Brüche*) in the earth's shell oppose to the propagation a very considerable obstacle.

It appears that the great rift of the *fossa magna*, first made known by Naumann, has played an important rôle in the seismic history of Japan.

F. OMORI. "Report of the Observation of Pulsatory Oscillations in Japan" (1st paper), *Bull. Imp. Earthq. Invest. Comm.*, Vol. III, No. 1, 1909, pp. 1–35; pls. 1–6.

This study, though carried out in Japan, was made in consequence of the resolution adopted at the 1907 conference of the International Seismological Association, and had for its object the observation of pulsatory movements on isolated islands and the comparison of the motions observed at several stations within a small area. Dr. Omori has found that these pulsatory motions of seismographs, as regards their periods of vibration, are practically the same all over the earth, and that they are probably due to the translatory movements and not to the inclination of the ground. There are found to be two mean periods of vibration: a short one, $Q_1 = 4.4$ seconds, and a longer one, $Q_2 = 8.0$ seconds. The movements occur very frequently, in fact almost constantly, on broad alluvial plains, though but rarely in places situated on granite or Paleozoic rocks. Though up to the present, they have generally been registered on instruments which record horizontal components only, they are found to have a vertical component as well. Marked pulsatory oscillations are connected with the approach of an area of low barometer, these movements being especially those of the shorter period.

W. H. H.

The Metallurgy of the Common Metals, Gold, Silver, Iron, Copper, Lead, and Zinc. By LEONARD S. AUSTIN. Pp. 494, $4.00.

In the second edition of this work much of the material has been recast and numerous text figures have been added, with about 100 pages of descriptive matter. This edition contains a comprehensive index, the lack of which was a serious omission to the first edition. The description of the cyanide process has been greatly amplified and much data relating to recent improvements in the practice are included. The metallurgy of zinc, the

methods of refining zinc and lead, and the manufacture of wrought iron and steel are fully treated. The writer's style is clear, concise, and entertaining. For a text introducing the subject to the student or to the mining geologist it is the best work which has come before the reviewer's notice. Its usefulness would be greatly increased, however, if it contained a bibliography. W. H. E.

Elements of Mineralogy, Crystallography and Blowpipe Analysis from a Practical Standpoint. Including a Description of All Common or Useful Minerals, the Tests Necessary for Their Identification, the Recognition and Measurement of Their Crystals, and a Concise Statement of Their Uses in the Arts. By ALFRED J. MOSES, E.M., PH.D., Professor of Mineralogy, Columbia University, New York City, AND CHARLES LATHROP PARSONS, B.S., Professor of General and Analytical Chemistry, New Hampshire College, Durham, N. H. 4th ed. Pp. 448 and 583 figures. New York: D. Van Nostrand Company, 1909. $2.50.

In the fourth edition of this useful work some of the material has been rearranged and the statistical data revised. The tables, with some additions, are essentially as in the previous editions. The book now includes an elementary course in crystallography in which the study of the photographs of actual crystals is utilized with the drawings of geometrical models of crystal. The course in blowpipe analysis and the tables placed at the end of the book are concise and reasonably comprehensive. The section on descriptive mineralogy includes much valuable data on the occurrence, origin, and uses of minerals. W. H. E.

Geology of Morgan County. By C. F. MARBUT. Missouri Bureau of Geology and Mines. Vol. VII, 2d series.

This county lies in southwestern Missouri, on the edge of the Ozark uplift. The chief rocks of the county are cherty, magnesian limestones, with thin bands of sandstone, Cambrian to Mississippian in age, with some Pennsylvanian shales and sandstones locally preserved. Fossils are not abundant and none have been described in this report. Lead, zinc, iron, barite, clay, and coal occur, and have been mined, but only the last three are mined at present. E. R. L.

Biennial Report of the State Geologist, Missouri Bureau of Geology and Mines.

The part of this report of general interest is the last chapter, a report on the mineral resources of the state. The value of the total output in 1907 is estimated at over $41,000,000, of which lead and zinc make up over $18,000,000. This is the largest in the history of the state. The growth of the output has been steady, and will doubtless continue. E. R. L.

The Geology of Pike County. By R. R. ROWLEY. Missouri Bureau of Geology and Mines. Vol. VIII, 2d series.

Pike County is located in the eastern part of Missouri, bordering the Mississippi River. It is essentially a region of hills, streams, and valleys in the eastern part, with more or less level prairie plateau in the west. The rocks consist of alternating limestones and shales, Ordovician to Pennsylvanian in age. They are practically horizontal and are, as a rule, highly fossiliferous. A number of species are described and figured, especially the fauna of the Louisiana (Lower Mississippian) limestone and the tribolites from the Ordovician. A short résumé would add greatly to the value of the report. E. R. L.

Report of Topographic and Geologic Survey Commission of Pennsylvania, 1906–1908.

The work of this commission is done in co-operation with the United States Geological Survey and the results published by the National Survey. The greater part of the present report is under the heading "Appendix E, Report of Progress of Co-operative Geological Survey." Of this the first part is a summary of geological work done in Pennsylvania and a review of the general geology of the state. Then follows a more detailed study of the southwestern part of the state. Except a small dike of peridotite which is reported from one of the mines near Masontown, Fayette Co., the rocks are all Paleozoic sedimentaries, Ordovician to Permian, with a covering of glacial and glacio-fluvial deposits in the southern part of the district.

Special attention is given to the economic resources, of which coal is by far the most important. Pennsylvania produces more coal than any other state or country in the world excepting Great Britain. In 1907 the coal mined was valued at nearly $320,000,000, over half of which was anthracite. Petroleum and gas, clay, and limestone products are also of great importance. E. R. L.